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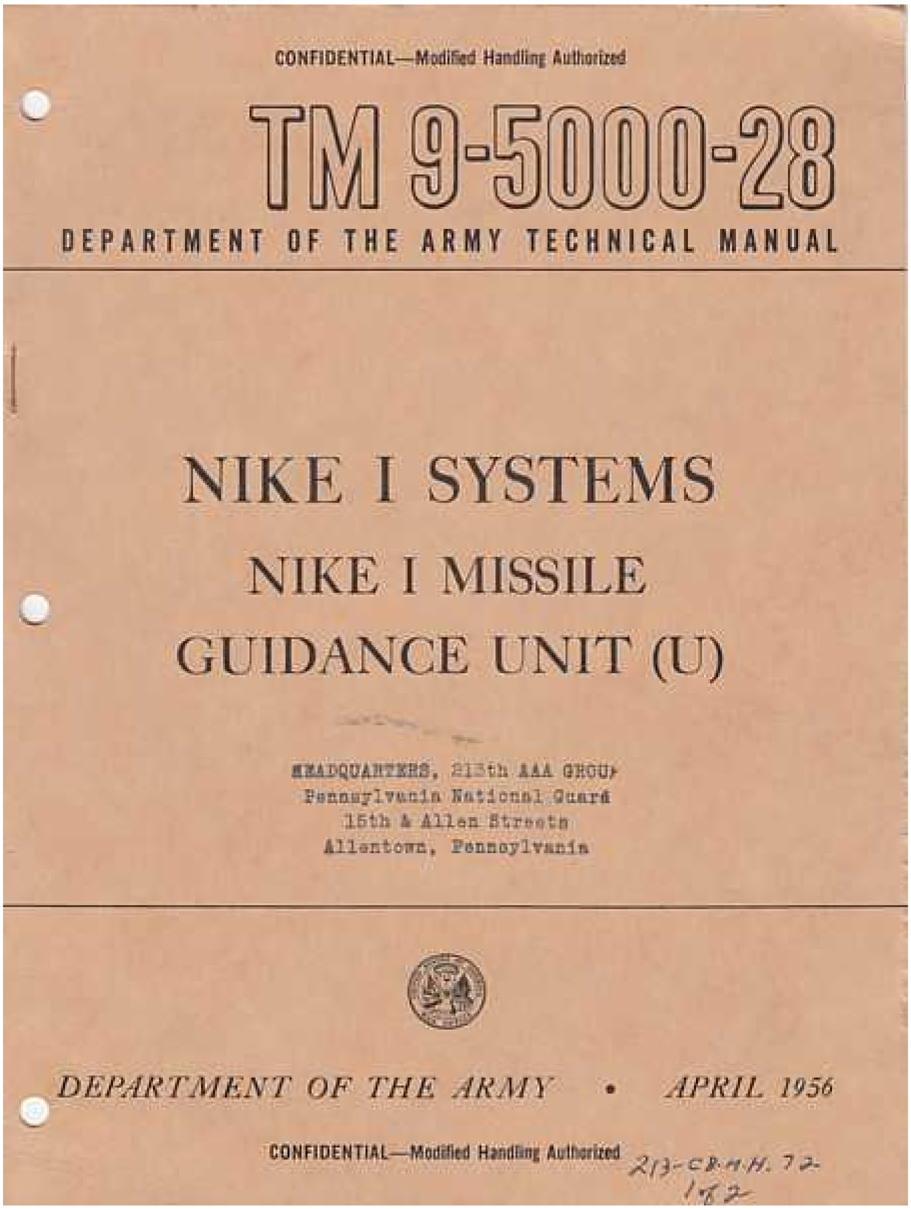
DEPARTMENT OF- THE ARMY TECHNICAL MANUAL

NIKE I SYSTEMS

Guidance Unit (U)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NIKE I SYSTEMS

NIKE I MISSILE

GUIDANCE UNIT (U)

HEADQUARTERS, 213th AAA GROUP
Pennsylvania National Guard
15th & Allen Streets
Allentown, Pennsylvania

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The special texts in the TM 9-5000-series are training supplements to those in the TM 9-5001-series which are the basic Army directives for the operation and maintenance of the Nike I Guided Missile System. In the event of conflict, technical manuals in the basic TM 9-5001-series will govern.

[AG 413.44 (5 April 56)] By Order of *Wilber M. Brucker,* Secretary of the Army:

Official: JOHN A. KLEIN,

Major General, United States Army, The Adjutant General.

MAXWELL D. TAYLOR, *General, United States Army, Chief of Staff.*

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CHAPTER I

INTRODUCTION

1. PURPOSE AND SCOPE

a. In order effectively to check out a Nike I missile, a knowledge of guidance section circuits and operation is essential. Also, in the event of a guidance unit malfunction, determination of the source of trouble is greatly facilitated through an understanding of its operation.

b. This text describes in detail the theory and operation of the electronic circuits of the GS-16725 guidance section assembly. The construction and operation of non-electronic components such as gyroscopes and accelerometers are explained, with special emphasis on the parts they play in the over-all operation of the missile guidance system.

2. REFERENCES

a. Much of the material presented in this text was compiled from the publication prepared by Bell Telephone Laboratories Inc .,on behalf of the Western Electric Company Inc., Guided Missile System, XSAM-A-7; volume III, Missile Guidance Section, GS-16725.

b. Additional information was obtained from the Surface-to-Air Section, Nike Branch, Guided Missiles Department, The Antiaircraft Artillery and Guided Missile School, Fort Bliss, Texas.

c. All figures in this text refer to TM 9-5000-33.

3. NIKE ON-MISSILE GUIDANCE SYSTEM FUNCTIONS

a. **General**. The Nike I missile (fig I-1) is controlled in flight by a guidance unit that programs the night in accordance with steering orders received from the ground guidance equipment. The steering orders are accelerations perpendicular to the pitch- and yaw-control fin planes. In order that the missile response to steering orders be stable and of correct magnitude, gyroscopes and accelerometers are incorporated within the guidance section to measure and govern the missile response.

b. **Purpose**. The guidance unit of the Nike I missile serves a dual purpose. First, it receives steering orders from the missile-tracking radar, interprets these orders, and supplies output control voltages to the hydraulic steering system and the warhead system. Second, it transmits a signal to the missile-tracking radar to permit radar tracking, because the missile does not present an adequate target for radar tracking using reflected energy alone.

c. **Steering orders**. To understand the manner in which steering orders to the Nike I missile are described, the basic concepts of acceleration must be considered. Acceleration results from a change in either the speed or direction of a moving object.

These two changes could occur simultaneously. Steering orders sent to the Nike I missile are measured in terms of the degree of lateral acceleration the missile must undergo to change its direction by a specified amount. This acceleration is indicated in terms of g's, one g being numerically equal to an acceleration of 32.2 ft/sec^2, which is the same as the acceleration due to the force of gravity. The maximum maneuvering acceleration perpendicular to the plane of each set of control fins is 5g. Orientation of steering orders is established in the missile by use of an unrestrained gyro, called a roll-position or roll-amount gyro. This gyro is used to roll-stabilize the missile in the flight position (fig I-4).

Roll stabilization is accomplished by means of ailerons on the trailing edges of the main (rear) fins. Due to the fact that the missile's fight attitude is with its control fin planes on an angle of 45^0 with the horizontal reference, both sets of control fins will act so as to give a maximum acceleration of 7.07g in a plane midway between the fins when maximum steering orders are transmitted to the pitch and yaw channels simultaneously.

The 5g acceleration in the direction perpendicular to the plane of the control fins is approximately the maximum acceleration that can be attained by full deflection of either set of control fins at an altitude of 40,000 feet and at normal velocities. The steering orders from the ground equipment are limited to this magnitude of turn in one plane to abide by structural considerations of the missile.

4. TIME SEQUENCE OF EVENTS

a. In the operation of a Nike I battery, a definite sequence of events takes place from the time of early warning until actual interception of the enemy aircraft by the missile. In some instances, the sequence of events must be maintained by personnel operating the system, while at other times the equipment itself automatically follows this sequence as a result of its design characteristics. This discussion is limited to that portion of the sequence of events which directly involves the missile. For a graphic representation of this sequence of events, refer to figure I-2.

b. The sequence begins when the target-tracking radar begins to track the target.

1. The target-tracking radar sends present position data of the target to the computer, where it is utilized to determine a predicted point of intercept of the missile with the target. At this time, the computer will also send roll-position gyro preset data to the missile through the Ag preset servo system.
2. The Ag preset servo system will preset the roll-position gyro so that its rotor is placed in a vertical plane through the launcher and the predicted point of intercept. During the first 4 seconds, the Ag preset data is inaccurate because this period is required for settling of the computer.
3. At the optimum time, as determined by the battery commander, the fire command is impressed upon the system. This sets into operation a 1.75-second timer in the launching control trailer. When this timer runs down, the launch order is initiated, uncaging the roll-position gyro and causing the booster squib to ignite 0.25 second later.
4. Booster burnout occurs approximately 2.5 seconds after liftoff, and separation from the missile takes place due to the greater air drag on the booster. As the booster falls free, a switch on the missile boattail section is released, electrically connecting the roll-position gyro to the roll system.
5. The missile will then roll while traveling vertically, to the gyro preset reference plane. This directs the belly of the missile toward the predicted point of intercept with the longitudinal axis of the missile lying in a vertical plane through the intercept point. A period of approximately 2 seconds is allowed for the missile to roll-stabilize in this position.
6. Five seconds after launch, the ground equipment sends a 7g dive order to the missile, causing it to dive toward the predicted point of intercept. This 7g dive order is maintained until the missile has reached an on-trajectory course. The 7g dive order to the missile is accompanied by the initial turn orders, which modify the 7g dive to a turning dive. This corrects for the error caused by the missile being launched from a position a few degrees off the vertical.
7. The critical zone is a space volume that is shaped like an inverted cone with the vertex at the MTR antenna. This conical volume would be traced out by the radar beam from the antenna if the beam reached its maximum elevation of 1,550 mils and rotated 6,400 mils in azimuth. The MTR cannot track a missile through this critical zone due to this limitation of antenna elevation during automatic tracking. If the critical zone lies between the launcher and the predicted point of intercept, the initial turn orders will cause the missile to skirt the critical zone. The only time the initial turn orders would not be present is when the launcher is facing the predicted point of intercept and the critical zone does not fall in between the two.
8. The radar cleared condition results when the computer determines that the missile will not pass through the critical zone. This may occur either before or after the on-trajectory course is reached depending upon the relative positions of the launcher, critical zone, and predicted point of intercept.
9. At the time the on-trajectory course is reached, steering orders are sent to the missile to guide it to the predicted point of intercept, which will change as the target maneuvers. Twenty-four seconds before intercept, the amount of steering orders to the missile greatly increases, keeping it closer to the desired course (1/2-order shaping).
10. Ten seconds before intercept, the amount of steering orders is doubled (full-order shaping), causing the missile to be very closely controlled so that abrupt changes in the position of the predicted point of intercept will not result in an excessive miss distance.
11. At 105.5 milliseconds before intercept, the burst order originates in the computer and the steering orders are removed simultaneously.
12. At 10 milliseconds before intercept, the warheads detonate, providing just enough lead to completely destroy the target.

5. MISSILE-TRACKING RADAR SYNC COMMAND SYSTEM

a. **General**. The command system translates the steering and burst orders from the computer into signals that are utilized by other systems of the radar for controlling a missile in flight. The steering and burst order information is conveyed to the missile, via the transmitted radar r-f beam, by modulating the pulse repetition rate of the missile tracking radar. To prevent two or more Nike systems from interfering with each other's missiles, the missile tracking radar transmits a simple 2-pulse code. Since these codes are predetermined and made different for each system, no battery can erroneously obtain control of the missile launched from another battery. The two pulses of the code are separated by an interval of time called the code interval.

b. **Operation**. Figure I-3 is a block diagram of the MTR command system. The missile steering order information is generated by the computer and is used to control the frequencies of the yaw oscillator and the pitch oscillator. This information from the computer is in the form of d-c voltages that will vary at the rate of 20 volts per g of steering order in either the yaw or pitch channel.

The yaw oscillator operates at a frequency of 150 cycles per second for a zero-g yaw command. The d-c voltage from the computer will vary this frequency from 120 cycles per second for a -5g command up to 180 cycles per second for a +5g command.

In a similar manner, the pitch oscillator operates at a frequency of 500 cycles per second for a zero-g pitch command. The d-c voltage from the computer will vary this frequency from 400 cycles per second for a -5g command up to 600 cycles per second for a +5g command.

The combined outputs of the yaw and pitch oscillators are applied to the contacts of a relay in the combining amplifier. The output of the burst oscillator is applied to another set of contacts on the relay. The relay is deenergized when the missile is being steered to the target, therefore applying the outputs of the yaw and pitch oscillators to the combining amplifier. The computer orders the burst of the missile by energizing this relay, which disconnects the output of the yaw and pitch oscillators from the combining amplifier and applies the output of the burst oscillator. The combining amplifier accepts the two simultaneous steering order signals and mixes the two equally to provide a definite operating range.

The combining amplifier supplies the repetition rate oscillator with signals that produce the same degree of modulation for either steering or burst orders. In the repetition rate oscillator, these signals are utilized to frequency-modulate the pulse repetition frequency. The pulse repetition frequency will vary between 1,600 cycles per second and 2,400 cycles per second, with a rest frequency of 2,000 cps. This corresponds to a variation in pulse repetition time of 416 to 625 microseconds about the rest period of 500 microseconds. The output of the repetition rate oscillator is applied to the pulse generator.

The pulse generator produces the preknock pulse that is sent to the radar presentation and ranging systems. The preknock pulse also initiates two other pulses within the pulse generator. These appear as a pulse pair at the output. The pulse of the pulse pair occurring first in time is the coding pulse, and the second pulse is the radar pulse. The time between these two pulses is the code interval. The code of the system may be changed by varying in time the position of the coding pulse with respect to the radar pulse. The radar pulse is not varied in time because this pulse is used to range on by the radar.

The two pulses are applied to the radar transmitting system, where they ultimately will trigger the magnetron. The output from the radar to the missile is a frequency-modulated train of r-f pulse pairs. The average period between pulse pairs is 500 microseconds. The rate at which this period varies between 416 and 625 microseconds depends upon the frequency of the yaw and pitch oscillators, or the burst oscillator, and therefore constitutes the command information.

6. DESCRIPTION AND LOCATION OF THE GUIDANCE UNIT (figs I-34 and I-47)

a. The guidance unit is the major assembly in the GS-15660 and GS-16725 guidance sections. The GS-15660 is an earlier model and the GS-16725 is a later one. The two guidance sections differ considerably in physical construction and appearance. Maintenance of the GS-16725 guidance section is easier than that of the earlier model, because of the facility with which parts may be replaced in the newer guidance unit. Electrically, both guidance sections are almost identical. Any differences will be explained as they are encountered in the description of guidance unit circuits.

b. The guidance section is located forward of the center warhead and aft of the steering control section. The tapered cylindrical housing for this section forms the skin for the missile from station 44.75 to 75.78 (station, in this instance, represents distance, in inches, from the nose of the missile). This section contains the guidance unit and battery case, radar antennas, and access ports for the various external guidance unit adjustments. Power- and test-plug openings are also provided. With the exception of the battery case, which is vented to the atmosphere, the entire guidance section is sealed to maintain launching barometric pressure.

7. GUIDANCE UNIT BLOCK DIAGRAM

a. General. The guidance unit consists of three basic systems (fig I-7). The beacon system or receiver- transmitter contains the receiving channel, decoding circuits, and the transponder or beacon itself. Figure I-ii is an interconnecting schematic diagram of the beacon system. The decoded information is sent to the signal data converter (steering order demodulator), which interprets this information and translates the separate steering orders into usable form. The command burst circuits are located in this unit. In the control section, the control amplifiers operate the hydraulic valves in the pitch, yaw, and roll channels.

b. Beacon system.

1. Antennas. There are four identical antennas mounted 90^0 apart around the circumference of the missile body at the rear of the guidance section. These antennas are in line with the control fins and the main fins. Two of the antennas mounted 180^0 apart are for receiving, and the other pair mounted similarly are for transmitting. Two of each are employed so that regardless of the flight attitude of the missile, there will always be one transmitting and one receiving antenna in line of sight with the missile-tracking radar. The streamlined external configuration of the antennas was dictated by wind tunnel tests.

2. R-F detectors. Cavity-type tuned circuits in the detectors select r-f energy of the frequency transmitted by the MTR. Crystal diodes within the cavities rectify this r-f energy. The rectified pulses are then filtered, providing a frequency-modulated train of d-e pulse pairs as the output of each detector.

3. Video amplifier. The d-c pulses that are the output of the detectors are very weak, especially at long ranges. The video amplifier amplifies these pulses to a level that will adequately operate the subsequent circuits.

4. Decoder-delay line. The amplified pulse pairs may not be the only output of the video amplifier because stray radar signals may be detected. Up to this point in the guidance unit, any input of the proper frequency will be passed. The decoder-delay line combination passes only the correctly coded information. The decoder will deliver one output pulse for each correctly spaced pair of input pulses.

5. Modulator. The modulator receives the output of the decoder. Each input pulse triggers pulse-forming circuits in the modulator that produce three simultaneous output pulses. A high-amplitude, short time-duration negative pulse goes to the magnetron, a positive pulse goes to the signal data converter command circuits, and a negative pulse goes to the fail-safe circuit in the signal data converter.

6. Magnetron. The magnetron oscillates whenever a pulse is applied from the modulator. This pulse is the energy that allows the MTR to track the missile. To further aid this tracking, the frequency of the missile magnetron is sufficiently different from the MTR transmitter frequency so that the MTR receiver, which is tuned for the missile beacon frequency, does not pass any echoes from its own transmitter.

7. Pattern modulator. The pattern modulator reduces trouble that could occur due to dead areas in the radiation pattern of the two transmitting antennas of the missile. These dead areas are due to cancellation of the r-f energy from each antenna. The pattern modulator is located in one of the transmitting waveguides and shifts the phase of the r-f energy in that waveguide at a rate of approximately 50 cycles per second. In this way, the dead zones are caused to oscillate at 50 cycles per second and the MTR cannot remain in a dead zone long enough to affect MTR-to-missile communication.

c. **Signal data converter (steering order demodulator)**.

1. Pulse stretcher and driver. The pulse width of the incoming train of FM pulses from the modulator is very narrow; consequently, the average voltage of the signal is quite small. The pulse stretcher greatly increases the pulse width without altering the command information, thus boosting the average signal voltage. The driver stage matches impedances between the pulse stretcher and filter unit.

2. Filter unit. The filter converts the rectangular-shaped FM pulses from the driver to a complex sine wave which is then separated into its simple sinusoidal components that represent the pure P and Y, or burst orders.

3. AGC amplifiers. Two automatic gain control amplifiers, one for the P- and one for the Y-channel, are incorporated in the signal data converter to amplify the P and Y a-c signals and provide a voltage output of constant amplitude to the P- and Y-discriminators.

4. P- and Y-discriminators. The discriminators convert the P and Y a-c signals to d-c voltages proportional to the frequency of the a-c signals. The d-c voltages have a polarity corresponding to the direction of the steering order and an amplitude proportional to the amount of steering order. The steering information is now in the same form as it was when it originated in the computer.

5. Command burst. The command burst circuits cause the burst action to be initiated when the burst command arrives from the MTR, provided the P and Y steering orders are no longer present. This prevents a premature burst, should the burst order erroneously be impressed on the beam during the midcourse phase while the P and Y steering orders are also present. The presence of the P- and Y-signals keeps the burst circuits in a disabled condition. Removal of these signals enables the burst circuits to respond to the burst order.

6. Fail-safe burst. The fail-safe circuit bursts the missile warheads in the event of system failure. A train of negative pulses from the modulator keeps the fail-safe circuit disabled. If system failure occurs, contact between the MTR and missile will be lost, removing the disabling pulses. The time for the fail-safe circuit to operate varies from 2 to 7 seconds precluding warhead detonation due to a momentary loss of contact with the MTR. Prior to launch, the warhead system is mechanically disabled so that this circuit has no control.

d. **Control section**.

1. P and Y control amplifiers. Two of these units are used in the control section to drive the hydraulic solenoid valves in accordance with signals from the

discriminators in the Signal Data Converter and the night control instrument.

2. Roll amplifier. The roll amplifier in the control section drives the aileron solenoid valve in accordance with signals from the flight control instruments. All inputs to the roll amplifier originate within the missile itself. Roll commands are not sent to the missile.

3. Fin and aileron potentiometers. A potentiometer wiper arm that picks off a voltage proportional to the amount of control-surface displacement is connected to each movable control surface. (P-fins, Y-fins, or ailerons). The fin potentiometer outputs are degenerative- or canceling type feedbacks going to their respective control amplifiers. These feedbacks do not take effect instantly upon a control surface movement but a very short time later. Thus, the control surface response is instantaneous and modified shortly thereafter.

4. P and Y rate gyros. The P and Y rate gyros exert their main effect during initial response to a steering order. Potentiometer wiper arms connected to the inner gimbal of these gyros provide a feedback voltage proportional to the rate of turn of the missile about its center of gravity (fig I-5). This feedback is also degenerative in its effect and prevents the missile from tumbling (going end-over-end) due to overcontrol.

5. Roll-rate gyro. The roll-rate gyro is less sensitive than the P and Y rate gyros. Roll-rate control limits fast roll rates during boost, before roll stabilization takes place. This gyro damps the missile's rolling oscillations about the normal flight position.

6. P- and Y-accelerometers. Two of these units are oriented in the guidance unit so that one is sensitive to lateral acceleration in the P direction and the other is sensitive to lateral acceleration in the Y direction. Each is mounted so that its sensitive axis is perpendicular to the pair of fins it monitors. The electrical output from each is derived from a potentiometer and is in terms of volts per g of lateral acceleration. As in the case of the other feedback voltages, this voltage is degenerative in its effect on the steering orders. The effect of the accelerometer feedbacks is the last to be felt in the control amplifiers. Nevertheless, these signals are the predominant ones and exert their effects for the longest period of time. An idea of the relative time durations and amplitude of the various feedback voltages can be obtained from figure I-22.

7. Pressure transmitter. The fin or aileron deflection necessary to cause a given missile response varies with missile velocity and with air density. Heavier air or faster speed requires a lesser deflection of a control surface to exert a given force on that surface. Stagnation pressure is the total pressure felt at the nose of the missile or at any area on the missile body that is facing into the missile's direction of flight. This pressure is a function of both missile velocity and air density.

   An opening in the nose of the missile permits this pressure to be transmitted through a tube to the pressure transmitter in the guidance unit. A potentiometer in the pressure transmitter is operated by this pressure, causing the P-, Y-, and roll-fin feedback voltages to be varied in amplitude in accordance with changes in stagnation pressure. A higher pressure results in a lesser fin deflection. At high stagnation. pressures, the missile response to movements of the ailerons is extreme. The increased aileron feedback resulting from the high stagnation pressure is not sufficient to balance out the input error signal to a level that will prevent overcontrol. Therefore, the gain of the roll amplifier is also directly controlled by another potentiometer in the pressure transmitter. With increases in stagnation pressure, this potentiometer will reduce roll amplifier gain.

e. **Power supply**. The basic electrical power source in the missile is the 28-volt nickel-cadmium battery that is mounted in a well in the forward portion of the guidance unit

housing. This battery is compact and rugged in construction, being designed to withstand severe altitude, temperature, and shock conditions. The power supply in the guidance unit receives this 28-volt power and by use of a vibrator and associated circuits provides the variety of voltages needed to operate the guidance unit. The power supply also provides a buzz or dither voltage, which is a 250-cps signal going to the solenoid valves.

CHAPTER 2

RECEIVER-TRANSMITTER DETAILED CIRCUIT OPERATION

8. ANTENNAS

Figure I-8 gives a cross-sectional view of a Nike I antenna. The antennas are faired, round waveguides of 0.9-inch inside diameter with a 45^0 minimum radius bend inclined toward the rear of the missile. A simple open end is used as an orifice at a distance of 3 inches from the missile surface. Mica-disk air seals are used on both ends of the tube to eliminate dust and dirt, and to allow pressurization of the guidance section.

a. **Polarization**. The r-f energy beamed by the missile-tracking radar is linearly polarized in the vertical direction, that is, its electrical and magnetic fields do not rotate in space, and the electric field vector lies in the vertical plane. Because the missile may be in various roll aspects with respect to the vertically polarized missile-tracking radar beam during portions of its flight, the missile receiving antennas must be able to accept the MTR beam and to couple efficiently a portion of this energy into the r-f detector cavities.

   This requirement for a universally polarized antenna matched to a vertically polarized r-f detector is satisfied by the use of polystyrene polarizers consisting of flat wedges of double V-notched polystyrene. One polarizing wedge is inserted in the S-inch length of round waveguide of each receiving antenna. Polarizing action of the polystyrene wedge is due to the dielectric constant of the polystyrene and the geometric configuration of the wedge itself, which combine to produce refractions and reflections in the plane of the electric field vector. This vector is broken up into component vectors, which are in turn reflected and refracted to produce a resulting electricfield vector lying in the plane of the crystal detector. An over-all 3-db power loss is sustained by the antenna receiving system due to attenuation introduced by the polarizing wedge. The polarizing wedges are positioned at an angle of 45^0 with respect to the plane of the crystal detector to permit a more uniform distribution of power over the plane of the crystal detector.

b. **Shadowing**. The antennas are aligned with the missile fins to obtain a minimum of shadowing by the main fins. The combined pattern of either set of antennas is essentially uniform over the area to the rear of the missile.

9. CHOKE JOINT

A choke joint (fig I-9) is used to couple the round receiving antenna waveguide to the r-f detector assembly. The connection between antenna and detector should appear as a low impedance so that r-f energy will pass the joint with little attenuation. If the choke joint makes contact with the detector assembly, the connection will appear as a low impedance because the choke joint will act as a shorted half-wave stub. If the choke joint does not make contact with the detector assembly, the connection will again appear as a low impedance with the choke joint acting as an open quarter-wave stub. Figure I-9 shows that the circular slot is a folded halfwavelength in length with the fold at the one -quarter-wavelength distance. The fact that the choke joint does not necessarily have to make mechanical contact with the detector assembly allows for mechanical movement, thermal expansion of parts, and misalinements at the joint.

10. COUPLING IRIS

The coupling iris is a thin metal diaphragm placed across the waveguide. It contains an H-plane (capacitive) aperture through which the r-f energy passes. The coupling iris matches the electrical characteristics of the waveguide antenna to the resonant cavity.

11. THE RESONANT CAVITY

As shown in figure I-36, the r-f detector cavity is formed by two converging sides of the waveguide section and is dimensioned to provide uniform sensitivity over the 8,600- to 9,400-mc operating range. The cavity has a nonuniform radius to provide low-Q, wide-band characteristics. Electrically, the resonant cavity is equivalent to a tank circuit; it presents a high load impedance to the frequencies to which it is tuned, and a low load impedance to other frequencies. The crystal detector is located in the geometric center of the cavity, which is the focal point of the energy reflected from various points along the converging walls of the cavity. Two resonant cavities are employed in the missile receiving system, one for each receiving antenna.

12. CRYSTAL DETECTORS

Figure I-10 is a diagram of the detector assembly. The crystal detectors used with the r-f detector assemblies are matched silicon diodes. They are designated as type 1N23B. The crystals convert the incoming r-f signal energy to d-c command signals by shunt limiting. The resulting d-c voltages are coupled to the video amplifier through two parallel-connected coaxial cables. The distributed inductance and capacitance of the coaxial cables serve as a filter to remove the r-f components from the d-c pulses. Because the two crystal detectors used with the guidance unit are electrically in parallel at the input of the video amplifier, the crystals must be carefully matched to prevent one crystal from loading the other. A d-c bias current of approximately 50 microamperes is passed through each crystal detector. This bias current is in the direction of crystal conduction, thus lowering the impedance of the crystals. This improves the crystal-to-cavity impedance match and also provides a low-impedance voltage source for the coaxial cable. If driven from a high-impedance source, the coaxial cable will tend to distort the d-c pulses. The pulse width of the incoming r-f pulses is 0.18 micro second. The output from the detectors is an FM train of d-c pulse pairs. The d-c pulse width will slightly exceed 0. 18 microsecond due to pulse stretching in the coaxial cables.

13. VIDEO AMPLIFIER (fig I-13)

a. **General**. The video amplifier is a 4-stage frequency-compensated amplifier, designed to have a gain of 70 decibels with a bandwidth of 6 megacycles. The 70-db gain provides sufficient amplification to boost a minimum signal level of 0.32 millivolt to a usable value of 1 volt. A maximum undistorted output of 6 volts may be obtained from the amplifier at close ranges. The 6-megacycle bandwidth provides sufficient amplification of harmonics of the fundamental frequency to preserve the shape of the input wave as it is amplifies.

b. **Crystal detector bias network**. Resistor R24, in conjunction with R30 and R31, drops the filament voltage down to approximately 0.2 volt to bias the two r-f detector crystals. Capacitor C22 and R24 filter out a-c noise voltages present in the filament circuit. Resistors R30 and R31 isolate the two crystals from each other while applying the required d-c bias. Capacitors C23 and C24· couple the detected pulses from the two r-f detectors to the grid of the first video amplifier stage while blocking the d-c crystal bias voltage.

c. **First stage**. The waveform applied to the grid of V1 is a positive pulse from which the r-f energy has been filtered. The amplitude of the pulse will depend upon the proximity of the missile to the missile-tracking radar. A 100-ohm resistor in the cathode circuit of this stage biases the tube to a negative 1 volt while the grid is operated at the low impedance of the biased crystal detectors. This biased impedance varies with individual crystals, but averages about 350 ohms.

The 1-volt, negative bias on the grid of V1 eliminates grid current flow, and the low grid-circuit impedance reduces the stage response to microphonic (tube noise) disturbances. To improve the high-frequency response of this stage, series peaking coil L1 is used in the plate load circuit. The value of this inductor causes it to resonate with the plate-to-ground capacity of V1, the grid-to-cathode capacity of V2, and stray wiring capacities at a frequency of about 6 megacycles. The negative pulses from the plate of V1 are developed across plate load resistor R3 and are applied through capacitor C3 to the grid of V2. This coupling capacitor is smaller than succeeding interstage coupling capacitors. The use of a smaller capacitor at this point prevents further amplification of microphonic disturbances without seriously affecting the pulse shape. This capacitor also determines the low-frequency response limit for flat response of the amplifier (about 100 kilocycles for 3 decibels down). The VI plate circuit decoupling from the B+ supply is provided by resistor R2 and capacitor C1.

d. **Second stage**. The negative pulse applied to the grid of V2 will have a positive overswing at the end of the pulse. This is caused by partial differentiation of the pulse by C3 and R5. Biasing V2 at zero volts minimizes this positive overswing while providing maximum amplification of the negative signal pulse. Series-peaking compensation is accomplished by L2, which resonates at: 6 megacycles with the interelectrode capacitance of V3 and the stray wiring capacitances. Resistor R6 and capacitor C4 constitute a plate supply filter and decoupling network for V2. The positive pulses from the plate of V2 are developed across plate load resistor R7 and are coupled to the grid of V3 through C5.

e. **Third stage**. At the third stage of amplification, the pulse has a fairly large amplitude and requires a negatively biased grid circuit. Cathode resistor R11 provides a 1-volt negative bias for the stage. Series-peaking compensation is provided by L3, which resonates at 6 megacycles with the interelectrode capacitances of V4 and stray wiring capacitances. Resistor R9 and capacitor C6 provide decoupling for the stage. At the output of this stage, considerable positive overswing appears at the end of the negative pulse. A crystal, CR1, is used to limit these overswings. The crystal, by passing current in one direction only, will pass the negative pulse and block the positive overswing. The negative pulses from the plate of V3 are developed across R10 and coupled to the grid of V4 through C8 and crystal CR1.

f. **Fourth stage**. Over the greater portion of the missile flight, the signal level at the input to the fourth stage will be sufficient to cause cutoff limiting to occur. Tube V4 is biased at zero volts to permit maximum tube characteristic limiting of signal overshoots. This stage uses shunt instead of series peaking in the plate circuit. The previous peaking inductors all resonate at 6 megacycles.

Without this frequency compensation, the frequency response begins to drop off at about 2 megacycles. The fourth stage peaking network is resonant at 4 megacycles to fill in the gap between 2 and 6 megacycles. Because all the peaking inductors are of the same value of inductance, a shunt type of circuit is employee: to obtain a lower resonant frequency. This is accomplished because the sum of the output capacitance of V4, the distributed wiring capacitance, and the input capacitance of V5 is greater than the input capacitance of the preceding stages. Resistor R16 and the internal resistance of V4 broaden the 4-mc peak in the frequency response curve of the video amplifier by reducing the Q of the resonant circuit. Resistor R14 and C9 accomplish decoupling for the stage. The effective 6-mc bandwidth of the video amplifier preserves a rise time of approximately 0.07 microsecond for the input pulse. The output of the video amplifier is a positive pulse and is applied through CIO to the input of the decoder. The noise level appearing at the amplifier output, due to the r-f detectors, is about 0.1 volt.

14. DECODER (figI-13)

a. **General**. A block diagram of the decoder is shown in figure I-12. The main components of the decoder are a pulse amplifier, a delay Line, and a coincidence or gating stage. The

pulse amplifier stage has a gain of approxmately three. The delay line is used to affect a time delay of the pulses going through it. The coincidence or gating stage is a pentode with grids 1 and 3 acting as control grids. Both grids are normally biased to cutoff. Either grid can hold the tube cut off, so that two coincident positive signals, one on each grid, are necessary to cause the tube to conduct and produce an output signal. The input to the decoder is an FM train of d-c pulse pairs with an amplitude of approximately a positive 1 to 6 volts, depending upon the distance between the missile and the MTR.

Pulse width is about 0.7 microsecond due to pulse stretching in the video amplifier. The output of the pulse amplifier stage is applied to two places, to grid 1 of the coincidence stage, and to the delay line. The delay time of the delay line is the missile code, but the coding interval of the pulses coming from the MTR is 0.1 microsecond greater than the missile code. The delayed pulses from the delay line are applied to grid 3 of the coincidence stage. Assuming the code spacing of the pulses being sent to the decoder to be corredt, the delayed code pulse will be on grid 3 of the coincidence stage 0.1 microsecond before the undelayed radar pulse arrives at grid 1 of the coincidence stage.. Thus, it is the undelayed radar pulse that triggers the coincidence stage and initiates the output pulse. This is the desired effect because the MTR ranges on the radar pulse and not on the code pulse. This single-output pulse from the decoder is positive in polarity and from one to three times the amplitude of the input pulse pair from the video amplifier. The FM train, of single d-c pulses coming from the decoder will have a pulse width of 0.75 microsecond due to pulse stretching in the preceding circuits.

b. **Circuits**. Tube V5 in the decoder is biased at approximately 1 volt by cathode resistor R21. Resistor R21 is bypassed by C14 to avoid degeneration. The positive pulses applied to the grid of V5 produce negative pulses on the primary of coupling transformer T1. This transformer is a 2: 1 step-down transformer used to provide an impedance match between the plate of V5 and the 1,100-ohm delay line.

The secondary of the transformer is connected so that positive pulses are applied to the delay line. These pulses are also coupled through C15 to grid 1 of the coincidence stage. Between the output of the delay line and grid 3 of the coincidence tube is a crystalCR2, which is used to attenuate any negative overswing of the positive pulses that might be caused by the delay line. The V6 gating stage generates a single negative pulse each time a positive pulse is simultaneously applied to both the control and suppressor grids.

The grid-limiting circuit consisting of resistor R26 and capacitor C19 prevents the positive pulse on the control grid from producing a heavy initial flow of grid current with a resulting overload of the secondary of T1. If the secondary of T1 is severely overloaded, the signal amplitude at that point will provide an input to the delay line so small that the output from the delay line to grid 3 of the coincidence stage may be too weak to drive the grid out of cutoff. Resistor R26 accomplishes the actual grid limiting while C19 couples the rapid amplitude changes past R26 to grid 1 of V6. Capacitor C19 preserves the sharp leading edge of the input pulse, which would normally be lost due to integration of the pulse by R26 and the input capacitance of V6. Both grids of coincidence tube V6 are biased at -7 volts with respect to the cathode. The cathode itself is connected to a negative 21-volt point on the heater supply through R28.

Connecting grid 1 and grid 3 through R25 and R23, respectively, to the -28-volt supply provides the needed -7 volts' cutoff bias. Capacitor C20 provides a direct a-c return to ground for the cathode circuit of V6, thereby isolating it from the filament supply. The d-c plate and screen voltage for V6 is supplied through a voltage divider consisting of R27 and R29. The effective plate supply is increased by the -21 volts applied to the cathode. Resistor R29, with capacitor C18, constitutes a plate supply decoupling filter for V6. The output of V6 is a negative voltage pulse developed across the primary of T2. The transformer is used as a 2:1 step-down transformer with its secondary connected so that a positive pulse is applied to the modulator. The gain of the decoder is between 1 and 3 for

properly coded pulses, while improperly spaced or single pulses are limited to outputs of less than 0.25 volt.

c. **Delay line**. The delay line is a plastic- or metal-encased distributed-constant type transmission line that is used to determine the coding interval as described in paragraph 12a. The delay time provided by the delay line is equal to the coding interval. Seven different delay lines are manufactured; each provides a different fixed time delay and each has a designed 6-db insertion loss. To obtain the fixed 6-db insertion loss, each delay line is internally terminated either by a single resistor or by a voltage divider consisting of two series resistors. The values of the terminating resistors depend upon the amount of time delay of each particular line and are chosen to provide the degree of delay line load mismatch necessary to obtain a 6-db insertion loss.

The delay line is similar in construction to a coaxial cable, having distributed series inductance and shunt capacitance. However, the series inductance and shunt capacitance per unit length of line are very much higher than for ordinary coaxial cable. The inductance is provided by a single layer coil of fine wire wound on a small-diameter core of insulating tubing. A 2-mil thick, plastic tape dielectric is wound over the wire coil, and a wire braid outer conductor is applied over the tape. The distributed capacity between the outer conductor and the wire coil is factory-designed to match the inductance of the wire coil.

The electrical signal impressed on the input terminals appears at the other end of the line after a definite time delay that corresponds to the code interval. The time delay is proportional to the length of the line and amounts to about one-half microsecond delay per foot of line with the maximum amount of delay being limited by the permissable waveform distortion and attenuation. The characteristic impedance of the delay line is 1,100 ohms. In the GS-16725 guidance section, the delay line is located at the forward end of the guidance unit and can be changed through the battery box opening. Ln the GS-15660 guidance section, the delay line is located about midway in the guidance unit and cannot be changed without removing the guidance unit. The time delay for a line is marked on its outer case. Delay lines are manufactured for the following delay times in microseconds: 2.5, 4.0, 5.5, 7.0, 8.5, 10.0, and 13.0.

15. RADAR MODULATOR

a. **General**. The signals received from the MTR are amplified and decoded, and are then applied to the modulator. The function of the modulator is threefold: First, the modulator generates a signal for firing the magnetron. This signal indicates the position of the missile and provides acknowledgement of the receipt of orders sent to the missile. Second, the modulator amplifies and shapes the decoded pulses for application to the signal data converter. These pulses contain the steering orders and, at the proper time, the burst order. Third, the modulator provides a cutoff bias to the fail-safe burst circuit.

b. **Modulator Block Diagram (fig I-14)**. The positive pulses from the decoder are amplified and used to trigger a blocking oscillator. Also, this blocking oscillator provides the output pulse to the signal data converter. The pulse forming network is charged through a resonant charging circuit to a value of nearly twice the supply voltage. When the blocking oscillator is triggered, it sends a high-amplitude, short-rise-time pulse to the thyratron. This pulse causes the thyratron to conduct, providing a discharge path for the pulse-forming network through the primary of the pulse transformer and through the thyratron. The pulse transformer steps up this pulse to a value large enough to fire the magnetron. Sufficient time elapses between input pulses to allow the pulse-forming network to recharge. The fail-safe cutoff bias pulse is taken off at the primary of the pulse transformer.

c. **Amplifier and blocking oscillator circuits (figI-15)**. The first section of V1 functions as a triode pulse amplifier. This stage is negatively biased to about -8 volts by a combination

of cathode bias of 1 volt developed across resistor R2 and heater string potential of -7 volts applied through grid resistor Ri. Positive pulses from the decoder are applied through C1 to the amplifier grid of V1. The positive pulse causes this triode to conduct heavily, resulting in the appearance of a negative pulse at the plate of the tube and across the primary of transformer T1. This negative pulse is coupled-over and appears as a positive pulse on the grid of the oscillator section of V1. The oscillator grid of V1 is biased at -14 volts.

This voltage is derived through a tap on the heater string through R4. The positive pulse from the transformer, appearing on the oscillator grid of V1, increases the plate current now through the tube. This action, in turn, increases the size of the negative pulse across the transformer primary. This process of regenerative feedback through the transformer continues until the oscillator section of V1 reaches saturation. At plate current saturation, the current now through the primary of T1 becomes constant and no voltage appears across its secondary. The voltage remaining on the oscillator grid is the negative 14-volt bias which then cuts off the tube. The magnetic field around the primary and secondary of T1 begins to collapse and, in collapsing, induces a voltage in the secondary of opposite polarity to that established during flux buildup. The voltage on the oscillator grid will then climb positively toward the negative 14-volt bias potential until the field around the primary has completely collapsed.

The blocking oscillator is now in its quiescent state and will remain so until another positive pulse from the decoder triggers it. The above-described regenerative process which drives the tube into saturation occurs very rapidly, producing a pulse with a very short rise time. This is essential in order to provide accurate triggering of the thyratron. Capacitor C5 couples the positive cathode pulse in series with the positive pulse appearing across the secondary of the transformer, improving the response time of the oscillator as well as increasing the amplitude of the output pulse to the thyratron. The positive pulse on the cathode is coupled through C2 to the signal data converter.

This pulse has an amplitude of about 120 volts and a duration of approximately 2 microseconds. The output pulse to the thyratron grid has an amplitude of about 300 volts and a duration of about 2 microseconds.

d. **Modulator network circuits**. The line-pulsing network, Zl, is terminated by its characteristic impedance at the pulse transformer primary. This network does not discharge exponentially like a capacitor but discharges abruptly, producing a flat-topped pulse across the primary of pulse transformer T2.

The charge path for the network is as follows: electrons flow up from ground through the primary of the pulse transformer to the negative plates of the network capacitors, from the positive plates of the capacitors through charging diode V2, inductor L1, and overload relay K1 to the 300-volt d-c supply. Diode V2 and inductor L1 enable the network to charge from the 300-volt supply to a potential of about 550 volts. When, during the charging process, the charge on the network reaches 300 volts, current flow through L1 ceases, causing the magnetic field in the inductor to collapse. As the field collapses, the lines of force in the inductor cut across its windings, inducing a voltage of a polarity opposite to that established during the buildup of the magnetic field.

This induced voltage is in series with the power supply voltage and thus raises its effective value to about 550 volts. The capacitors in the network charge to this 550 volts. At this time, the magnetic field in the inductor has completely collapsed. Diode V2 prevents the capacitors in the network from discharging back through the power supply down to a potential of 300 volts. The positive pulse output of blocking oscillator V1 is coupled through C4 to the control and shield grids of thyratron V3. These grids are biased to a negative 60-volt potential, which is applied through R5 and L3 in parallel.

Inductor L3 provides a low d-c resistance and a high a-c impedance in the grid circuit of the thyratron to prevent loading down the blocking oscillator output pulse. When the 300-volt output pulse from the blocking oscillator is applied to the thyratron grids, the tube ionizes and conducts, providing a low-impedance discharge path for pulse-forming network Z1. The network discharges down through the primary of the pulse transformer to ground and up from ground through the thyratron and back to the positive plates of the capacitors in the network. Discharge of the network produces a flat-topped voltage pulse of 275 volts amplitude and 0.25-microsecond duration across the pulse-transformer primary. Inductor L2 limits the surge current through the thyratron during discharge of the network.

Pulse transformer T2 is designed to step up the square-topped 275-volt pulse output of the Z1 network to a negative, 3,900-volt pulse capable of firing the magnetron. The pulse transformer is designed to match the 26-ohm impedance of pulse-forming network Z1 to the apparent 5,500-ohm load impedance of the magnetron. Upon discharge, the 550-volt charge of the Z1 network is divided evenly between the network itself and the 28-ohm impedance of the primary of the pulse transformer. The pulse transformer has a bifilar secondary consisting of two matched windings. Filament current for the magnetron is fed through the bifilar windings to each side of the magnetron filament. The negative 3,900-volt secondary pulse appears across both bifilar windings and is therefore applied to both sides of the magnetron filament. This eliminates voltage stresses on the filament such as would occur if only one end were negatively pulsed, and permits the use of a magnetron filament transformer having low-voltage insulation on its filament winding.

Capacitor C10 allows the pulse current to divide equally between the two secondary windings. Also incorporated in the pulse transformer is a flux bias winding. Magnetic flux due to the flow of magnetron filament current through this winding is in opposition to the flux created by pulse current and permits the use of a smaller core in the transformer without core saturation occurring. Overload relay K1 is a normally closed relay placed in the plate circuit of the charging diode. This relay is designed to operate at a specified current level. The normal Z1 network charging current is not sufficient to energize the relay. However, if thyratron discharge tube V3 fails to extinguish (deionize) after network discharge, the thyratron current flow through V2 to the 300-volt power supply will energize the relay, opening the plate circuit and forcing deionization of the thyratron. Capacitor C6 and resistor R7 constitute an are suppresser.

16. MAGNETRON

The Nike I guidance unit utilizes a type 6229 magnetron to furnish the beacon return pulse. The magnetron is a cavity resonator-type employing a grounded anode and a negatively pulsed cathode to generate 0.25-microsecond 700-watt pulses of r-f energy. The average power output of the magnetron is 0.35 watt. The resonant cavity section of the magnetron is the symmetrical "strapped vane" anode composed of 12 resonant cavities cut into the anode block and extending outward from the concentric cathode.

The straps connect alternate vanes that are of equal potential and pass over adjacent vanes which, at the mode frequency, are 180^0 out of phase. This is called the pi mode of operation. The output frequency of the 6229 magnetron is tunable from 8,900 to 9,400 megacycles by means of a tuner shaft that varies the cavity dimensions. The frequency is adjusted to be different than that of the MTR to allow the radar to distinguish the beacon signal from reflected signals of its own beam. The magnetron tuner shaft is accessable from outside the guidance section casting by removal of the -P antenna (antenna 3), 180^0 from the antenna marked +P on the housing casting. The r-f output of the magnetron is coupled directly into the waveguide by means of an exponentially tapered output transformer. Physically, the transformer is an extension of the anode block of the magnetron.

17. WAVEGUIDE AND PATTERN MODULATOR

a. **Transmitting waveguide**. The transmitting waveguide assembly consists of a length of 1/2-inch by 1-inch rectangular waveguide flared on each end to provide a transition to the round 1-inch antenna. The two ends of the waveguide are provided with round choke plates to couple the two transmitting antennas. The 6229 magnetron is fastened directly to the transmitting waveguide and feeds directly into it. A resistive strip attenuator is cemented to the waveguide wall immediately below the magnetron. The attenuator is a Bakelite strip coated with a resistive material that is placed longitudinally in the waveguide with the plane of the strip parallel to the narrow dimension. When the waveguide is excited with r-f energy-from the magnetron, currents now in the resistive material and energy is dissipated in the form of heat. The attenuator reduces the pulling effect (shift in magnetron frequency) on the magnetron due to the pattern modulator, and reduces reflections due to impedance mismatch between the rectangular and round waveguide, and between the open-ended round waveguide and the air.

b. **Pattern modulator**. The pattern modulator is a small dielectric semicircle that is rotated into and out of the waveguide E-plane through a slot in the waveguide wall. The disk is attached to the counterbalanced shaft of a small 2-phase a-c motor. The motor is a capacitor-start, capacitor-run motor powered by a 45-volt, 250-cps supply. The pattern modulator varies the relative phase of radiation of one antenna with respect to the other at approximately a 50-cps rate. This rate is somewhat lower than can be handled by the missile-tracking radar AGC circuits, so that a stationary pulse is observed on the radar presentation system. By varying the relative phase radiation of one antenna with respect to the other, zero-energy points that would tend to occur in the combined radiation pattern of two constant phase antennas are "wobbled" out and a more uniform radiation pattern is achieved.

CHAPTER 3

SIGNAL DATA CONVERTER CIRCUIT OPERATION (Figure I-21)

18. PULSE STRETCHER

a. **General**. The width of the input pulses to the signal data converter is very small compared with the interval between pulses. Because the duration of the pulses is short, their actual power level is low. By increasing the pulse duration, the energy content of the pulse train may be increased without changing the frequency-modulated information. The stretching of the received pulses makes it practicable to separate the information contained in the pulses into the desired command channels by the use of filters. The pulse stretcher is a monostable multivibrator which utilizes the input pulse to the signal data converter as a trigger pulse. The natural period of this multivibrator is 200 microseconds. Because the input pulses arrive from 416 to 625 microseconds apart, there is no danger of the multivibrator not having time to cycle before the next input pulse arrives. The leading edge of the 200-microsecond rectangular wave output of the pulse stretcher is coincident in time with the input pulse, and therefore is also frequency- modulated.

b. **Operation**. In the following discussion, the triode section of V1 connected to pins 5, 7, and 8 will be called V1A and the triode section connected to pins 1, 2, and 4 will be designated as V1B. The circuit is set up so that with operating voltages applied, V1A will be held at cutoff by a negative bias of about -7 volts that is obtained from the voltage divider consisting of resistors R1, R2, and R5 and applied to the pin 7 grid. At this time V1B is conducting with a slightly positive grid voltage applied through R4. Nonconducting V1A plate voltage is +150 volts, and the V1B plate voltage is approximately +50 volts. When the positive input pulse drives V1A into conduction, its plate voltage will fall negatively 140 volts to a value of about 10 volts.

This negative-going voltage is coupled by C3 to the grid of V1B. This cuts off V1B, and its plate voltage rises to +150 volts. Part of this high V1B plate voltage is coupled to the grid of V1A, keeping V1A conducting heavily. Tube V1B now has a grid voltage of

approximately -140 volts, maintained by the charge on C3. Capacitor C3 begins to discharge through R4 and the grid voltage of V1B rises exponentially toward +150 volts at a rate determined by the RC time constant of C3 and R4. When the V1B grid voltage rises to about -5 volts, V1B conducts and its plate voltage falls negatively, carrying the grid of V1A along with it because of coupling by Ri and C2. The multivibrator is now again in its quiescent condition with V1A cut off and VIE conducting. Another input pulse is needed to cause the multivibrator to repeat the cycle described above and produce a 200-microsecond output pulse.

Since the plate voltage of V1B will change from f50 volts for the quiescent condition to +150 volts when it is cutoff during the multivibrator operation, the output pulse will be positive and have an amplitude of about 100 volts. The 0.6-microsecond input pulse must have an amplitude of 20 volts or greater in order to trigger the multivibrator. Negative overswing of the trigger pulse due to input grid current now would tend to cut off the multivibrator and terminate pulse-stretching action. The unidirectional conducting characteristics of crystal CR1 eliminate the negative overswing and insure proper triggering of the multivibrator.

19. CATHODE FOLLOWER DRIVER

a. **General**. Cathode follower stage V2 couples the high-impedance signal output from the stretch multivibrator to the low impedance presented by the filter unit. The cathode load resistor R9 provides a nonreactive driving source that assures a uniform impedance match at all frequencies.

b. **Circuits**. The pulse input is coupled through capacitor C4 to two parallel connected grids. Resistor R8 acts as a parasitic suppressor by decoupling the grids. Resistors R6 and R7 constitute a voltage divider to provide a grid-to-ground reference of +75 volts. By maintaining a high grid reference level, the tube operates,with a transconductance value sufficient to keep its output impedance at a minimum value of between 100 and 300 ohms. This 300 ohms, in series with the 8,200-ohm resistance of R10, provides the input impedance of 8,500 ohms to match the filter unit.

20. FILTER UNIT

a. **General**. The input section of this unit, called the low-pass filter (0-1,150 cps), restores the audio command frequencies from the frequency modulated train of input pulses. This input filter section attenuates all frequencies above 1,150 cycles per second by 70 decibels. The complex audio frequency wave is then sent into three separate filters, one for each command channel: a 400- to 600-cps bandpass filter for the P-channel, a O- to 180-cps low-pass filter for the Y-channel, and an 800- to 900-cps bandpass filter for the burst channel. Each of these three filters possesses about 40 decibels of attenuation to frequencies in the other two channels. The final outputs from the filter unit are three sine waves, the frequency of each depending upon the nature of the command being sent to the missile.

b. **Physical construction**. The filter unit is cast into a cylindrical resin casting 5-3/4 inches in diameter and 2-1/4 inches high, weighing 4-1/2 pounds. Slightly more than one-half this total weight is due to the weight of the resin casting. The casting material is a thermosetting styrene polyester resin known commercially as Stypol. This material provides component rigidity, uniform heat dissipation, and resistance to chemical fumes, moisture, and corrosion.

21. AGC AMPLIFIERS

a. **General**. For proper operation of the P- and Y-discriminators, their input signal amplitude must be nearly constant. To accomplish this, two automatic gain control amplifiers are incorporated in the signal data converter: one for the P-channel and one for the Y-channel.

The circuits and operation of these amplifiers are identical. For a block diagram of an AGC amplifier, refer to figure I-16.

b. **AGC amplifier and discriminator drive stage operation**. The P and Y AGC amplifiers are identical, so only the P-amplifier will be discussed. The input signal from the filter is adjusted to a value of 0.15 volt rms by potentiometer R13. This signal is fed through C5 to the grid of pentode V3. Tube V3 amplifies the signal to a value of approximately 3 volts rms. The network consisting of C7, R18, C8, R19, and R20 couples the signal from the plate of V3 to the grid of V4. This network also provides a shaping effect upon the signal to prevent oscillations from developing in the amplifier due to feedback that occurs through the AGC circuit. The signal is amplified by V4 to about 54 volts rms, and is used to drive the discriminator circuits.

Due to nonuniform loading of the amplifier by the diodes in the discriminator, distortion of the output signal results. This is characterized by one half-cycle of the sinusoidal signal having a greater amplitude than the other half-cycle. This difficulty is overcome by employing negative feedback in AGC amplifier. A special winding on the coupling transformer applies a portion of the output signal to the cathode of power amplifier V4. This voltage is in phase with the signal voltage on the control grid of V4, and as such is negative feedback. This feedback circuit lowers the effective impedance of the driver stage to approximately 1,500 ohms, rendering it relatively insensitive to load variations.

c. **The AGC circuit**. The automatic gain control circuit consists of clamping stage V5B, peak rectifier stage V5A, and delayed ACC stage V6A. From the plate circuit of power amplifier V4, the 75-volt peak signal is utilized to furnish the excitation voltage for the AGC circuit. This 75-volt sine wave is first clamped negatively below a positive 18-volt reference by V5B and C10. The +18-volt control signal voltage is used for this purpose so that the AGC amplifier output voltage will be dependent upon any variations in this reference potential. Due to the clamping action, the voltage across C10 becomes stabilized at about -57 volts direct current. The capacitor now acts like a battery in series with the a-c signal voltage, and the potential on the cathode of V5A represents the sum of the charge of C10 and the instantaneous value of the applied a-c signal voltage. The resulting negatively biased signal is applied to diode V5A and produces current now through the diode and through resistors R26, R25, and R24 to the +18-volt supply. Capacitor C9 is then charged to a small negative voltage.

The value of the negative charge on C9 depends upon three factors: (1) the amplitude of the P-channel output signal, (2) the value of the +18-volt control signal reference voltage, and (3) the setting of P LEVEL ADJUST potentiometer R26. Therefore, the voltage across C9, is equal to the voltage difference between the +18-volt supply and the drop across R24. Any change in current flow through R24 results in a change in voltage across capacitor C9. The negative charge on C9 acts as bias on V3 to determine the gain of the amplifier. Through the action of the AGC circuit, any variation in output will cause a change in amplifier gain that will restore the channel output to its original value. The amplifier and AGC control stage V3 is set up to operate with a d-c bias of approximately -3 volts. Diode V6A is a positive limiter biased at a potential of -2.5 volts. Diode V6A permits the bias on V3 to go no more positive than -2;5 volts, preventing the AGC circuit from applying the +18-volt control signal voltage as bias to V3. In actual operation, the AGC bias voltage will vary between -2.5 volts and approximately -8 volts.

22. P- AND Y-DISCRIMINATORS

a. **General**. The final action of the signal data converter upon the signal is the changing of the signal information into a d-c voltage. The polarity of this voltage indicates the: direction of the steering order, and its amplitude indicates the magnitude of the order. The discriminator section of the signal data converter performs this function. It accepts the a-c signal from the AGC amplifier and converts it into a d-c signal, the amplitude and polarity of which depend upon the frequency of the a-c signal input. The circuits of the P- and Y-

discriminators are similar, differing only in the resonant frequencies of their input impedance networks. Both discriminators are ratio detectors and their circuit operation is identical.

b. **Operation**. The output voltage from the AGC amplifier (about 35 volt root-mean-square) is applied to two series-connected, series-parallel resonant circuits (impedance networks). Each set of impedance networks is tuned to resonance with one network tuned just below the lowest command-channel frequency and the other network tuned just above the highest command-channel frequency. For the P discriminator, one network is tuned to 380 cycles per second and the other to 620 cycles per second (fig I-17). Since the P-channel covers from 400 to 600 cycles per second, the 380-cps network is operating on the inductive side of resonance and the 620-cps network is operating on the capacitive side of resonance. In other words, one of the impedance networks is operating with inductive impedance ($R + jX_L$) and the other is operating with capacitive impedance ($R - jX_C$). Also, for any given frequency, the algebraic sum of their separate impedances is equal to a constant value of pure resistance.

These series-parallel resonant circuits are designed so that the frequency that produces an equal a-c voltage across each network is the frequency corresponding to a zero steering order. This frequency is 500 cycles per second in the P-channel and 150 cycles per second in the Y channel. As the frequency deviates from this center or rest frequency, the voltage across one network decreases and the voltage across the other increases. The direction of deviation from the center frequency determines which network develops the greater voltage. Therefore, the impedance networks are frequency selective devices and their a-c signal output amplitude is dependent upon the frequency of the input signal. The a-c voltage developed across each impedance network is connected to a diode rectifying circuit through the plate of V7A and the cathode of V7B (fig I-18). The +18-volt control signal reference voltage is connected to the cathode of V7A, and the -18-volt control signal reference voltage is connected to the plate of V7B.

Filter section components R_E and R_F reduce the level of any a-c command signal voltage present in the d-c command output. Normal current flow through R_A and R_B from the 36-volt control signal supply tends to establish point H at zero volts with respect to control signal ground. Tube elements of V7 are connected so that current flows only, when the peak. a-c input voltage exceeds the 36-volt reference potential. When conduction does occur, the division of voltage across the two impedance networks causes currents to flow into CA and CB, charging these capacitors. If the voltages developed across the two impedance networks are equal (as occurs when a zero order is present), the d-c voltages across CA and CB will be equal, and point H will remain at zero volts with respect to control signal ground.

If the frequency applied to the two impedance networks is raised, more voltage will be developed across CB then across CA, and point H will swing positive with respect to control signal ground. If the applied frequency decreases, more voltage will be developed across CA than across CB. The voltage of point H will swing negative with respect to control signal ground. Therefore, d-c output of the discriminator is a function of frequency with the center frequency producing zero volts. The discriminator output varies at the rate of 1.92 volts per g of applied Steering order. This corresponds to 1.92 volts per 20 cycles per second of frequency deviation in the P-channel, and to 1.92 volts per 6 cycles per second of frequency deviation in the Y-channel. The maximum deviation from a linear plot of output voltage versus input frequency is less than 0.4 volt.

c. **Effects of control signal voltage variations**. If the control signal voltage ground is maintained at the midpoint, reasonable changes in the value of the +18 volt control signal voltage supply that biases the V7 diodes in the discriminator will not affect the d-c output signal voltage. in actual operation, the discriminators are sensitive to changes in input signal amplitude. This is due to the nonlinear operating slopes on the resonant curves of the two impedance networks in each discriminator. As a result, increases (decreases) in the

input signal amplitude will cause increases (decreases) in the d-c output voltage. This characteristic of the discriminators justifies the employment of AGC amplifiers as drivers for the discriminators.

Because the +18-volt control signal voltage is used as a clamping reference in the AGC amplifier circuits, the outputs of the AGC amplifiers are dependent upon changes in the +18-volt reference. An increase (decrease) in the +18-volt reference will cause an increase (decrease) in the output signal amplitude of the AGC amplifiers. This will, in turn, cause a corresponding increase (decrease) in the d-c output voltage from the discriminators. The +18-volt control signal supply is used as a voltage source for the potentiometers in the steering control instruments (fin pots, gyros, accelerometers). Therefore, an increase (decrease) in the control signal voltage will cause an increase (decrease) in the amplitude of the degenerative feedback voltages from the flight control instruments.

While an increase (decrease) in the control signal voltage causes an increase (decrease) in the amplitude of the feedback signals that tend to cancel the steering orders, this increase (decrease) in control signal voltage also causes an increase (decrease) in the d-c output from the discriminators. Thus, changes in the control signal supply voltage cause simultaneous changes in both feedback amplitude and steering order amplitude, maintaining correct relationships between all controlling signals in the missile.

23. COMMAND BURST CIRCUIT

a. **Block diagram (fig I-19)**. For the command burst circuit to operate, P and Y steering orders must be removed and the burst order must be applied. The presence of the P and Y orders disables this circuit so that it will not send a pulse to the detonator even though a burst order is present. Signals from the P and Y AGC amplifiers are rectified by detector V12, and positively limited below a positive 22 volts by diode V16A. These positive 22-volt pulses charge C19, and this positive potential is used as bias on the burst clamp tube, V17. Due to the large voltage drop across R61, the burst clamp tube keeps the potential on the plate of the burst thyratron, V18, down to approximately +20 volts. The thyratron cannot fire with such a low cathode-plate potential.

Burst orders from the filter unit are amplified and clipped by V13, then clamped negatively and rectified by V14. This negative output from V14 is impressed upon the grid of the burst clamp tube. With the P and Y steering orders furnishing a positive voltage to the burst clamp grid and the burst order furnishing a negative voltage, the grid voltage of the burst clamp tube will be nearly zero volts. This is still positive enough to maintain heavy enough conduction through the burst clamp tube to keep the plate of the burst thyratron at approximately 20 volts. The burst clamp tube will unlock only by removal of the P and Y orders. The burst order from V13 is also sent through V15, where it is clamped positively above a -28 volt reference and rectified. Without the burst signal being present, capacitor C24 is charged to a -18 volts.

When the burst order is applied, the positive signal from V15 discharges C24, removing the negative bias from the grid of the burst thyratron. If, at this time, the P and Y steering orders had been removed, the thyratron would fire, discharging C29 through the detonator.

b. **Amplifier stage V13**. The burst order output of the filter has an amplitude of about 2.5 volts' root-mean-square. This voltage must be amplified and rectified to obtain the required d-c burst command voltage. The 2.5-volt root-mean-square signal is developed across resistor R51 at the output of the filter unit and coupled through capacitor C20 to the grid of amplifier V13. The grid is biased by a voltage divider network consisting of resistors R52 and R54. Resistors R55 and R56 constitute a similar network designed to apply a positive 40 volts to the screen grid. The amplifier stage provides early limiting of the input signal by using a large plate load resistor in conjunction with a low screen-grid potential. Grid bias through R54 is sufficient to hold the tube at cutoff for low-level signals but is small enough to permit normal-level signals to overdrive the tube in both the

positive and negative directions. Signal limiting reduces the effect of noise voltages and reduces the effect of signal amplitude variations.

c. **Voltage doubler V15**. Capacitor C24 is normally kept charged at a negative 18 volts by a voltage divider consisting of resistors R64, R63, and R62. The a-c burst order signal, which has been amplified and clipped by V13; is fed to a detector limiter stage consisting of diodes Vl5A and V15B. V15B and C22 clamp the signal positively above a -28-volt reference. Upon application of the burst signal, this detector limiter operates to discharge capacitor C24 removing the -18 volt cutoff bias from the grid of burst thyratron V18.

d. **Detector V12**. Both the P and Y AGC amplifier output signals are coupled to the plates of diode detector V12. These signals are rectified by the detector and the resultant d-c voltage is applied to capacitor C19. The positive charge on capacitor C19 is coupled to the control grid of the burst clamp tube V17 insuring continuous conduction of the tube. A limiter stage V16A prevents the voltage on C19 from rising above a positive 22 volts, a voltage established as a timing reference point. The cathode of V16A is returned to a positive 22-volt reference to permit this limiting action. A negative voltage of approximately -14 volts is obtained from a tap on the heater string and applied through balanced resistors R48 and R49 to the detector plates. This small negative voltage prevents the rectification of low-level noise voltages that appear at the output of the P and Y AGC amplifiers, and also prevents loading of the circuit when proper signals are present.

e. **Detector V14**. The a-c burst signal that has been amplified and clipped by V13 is fed to a detector circuit consisting of diodes V14A and V14B and capacitor C21. Tube V14B and capacitor C21 clamp the burst signal negatively below a zerovolt or ground reference. Tube V14A is a positive series limiter. The negative signal from this detector circuit charges capacitor C23 negatively with respect to ground. A portion of the negative voltage appearing across C23 is applied to the grid of burst clamp tube V17 through a voltage divider formed by resistors R58 and R59. Tube V17 is normally conducting due to the P and Y command voltages, which are rectified and applied to the control grid, keeping it slightly positive.

This summation of control voltages is such that the control grid of V17 remains near zero volts, and the tube conducts as long as P or Y orders are present, even though burst orders are also present. The grid can only be driven negatively by removing the P and Y orders and applying the burst order. With the grid of burst clamp tube V17 held slightly positive, plate current now through plate-load resistor R61 produces a large voltage drop across the resistor. Since the burst thyratron plate voltage is taken in series with this resistor, insufficient voltage is available to fire the thyratron while the burst clamp tube is conducting. When the grid of the burst clamp tube is driven negatively, and the tube goes into cutoff, plate current now through R61 stops, and capacitor C29 charges as the plate voltage rises toward the plate supply of 230 volts.

f. **Burst clamp stage V17**. When burst orders only are present, a negative voltage appears across R59 due to the action of detector V14. This voltage biases the tube to cutoff, allowing the plate voltage to rise. Capacitor C25 provides a negative feedback path that reduces the rate of plate voltage rise and fall.

g. **Burst thyratron V18**. The pulse which is delivered to the warhead detonator has an amplitude of 120 to 200 volts and an energy content of 15,OO0 ergs. This pulse is obtained by the discharge of capacitor C29 through burst thyratron V18. Since the plate voltage of the burst thyratron is taken in series with the plate load resistor of the burst clamp tube V17, the plate voltage of V18 is limited to about 20 volts by the series drop across R61 due to current flow through V17. Burst thyratron cathode voltage is obtained from the plate voltage supply through a voltage divider consisting of resistors R65, R66, R67, and R68.

BURST TIME adjustment: R66, shunting R65, varies this voltage between a positive 7 and 21 volts. Thyratron grid bias is supplied from the plate voltage supply through a voltage divider consisting of resistors R62, R63, and R64. Removing the positive bias from the burst clamp tube reduces plate current flow through R61 and raises the burst thyratron plate voltage. This voltage rises at a rate determined by capacitor C25 in the burst clamp circuit and the R-C time constant of C29 and R61.

The time delay introduced by C25 prevents preburst of the detonator due to very short steering order signal lapses. The application of burst orders to the circuit effectively grounds the junction of R63 and R64 due to the discharge of capacitor C24. Then, as the plate voltage rises, the grid bias voltage rises, and when the combination of rising plate and grid voltages reaches a critical value, the burst thyratron fires, discharging capacitor C29 through the detonator to ground, and up from ground through the burst thyratron. The charge path for C29 is up from ground, through R69, and through R61 to the positive 230-volt supply.

24. FAIL-SAFE BURST CIRCUIT

a. **General (fig I-20)**. The fail-safe burst circuit consists of twin diode V19, thyratron V20 and associated filter network, and burst-discharge capacitor C34. The fail-safe burst circuit provides an alternate, self-initiated method for detonating an uncontrolled missile's warheads and destroying the missile. Self-destruction of an uncontrolled missile is necessary to protect populated areas and ground installations from damage. The circuit becomes operative and generates a burst pulse in case of failure of the missile guidance unit or if the missile-tracking radar loses control over the missile. Fail-safe time for the missile varies from 2 to 7 seconds. If, during this period, the missile-tracking radar reassumes control over the missile, the fail-safe burst circuit is returned to normal.

b. **Operation**. Negative 275-volt pulses from the pulse-forming network in the modulator are fed through isolating diode V19A to charge capacitor C33 negatively. The -275-volt charge on C33 is applied to the control grid of the thyratron V20 through a voltage divider consisting of resistors R78 and R79. The ratio of resistances of R78 to R79 is such that about one-eleventh of the charge on C33 appears on the thyratron grid. Capacitor C32 and resistor R77 filter the incoming pulse train so that spurious signals will not appear on the thyratron grid. The negative voltage from C33 on the thyratron grid will hold it at cutoff. Isolating diode V19A prevents C33 from discharging back into the modulator and isolates the components of the fail-safe circuit from the modulator circuitry.

In the plate circuit of thyratron V20, capacitor C34 is charged to 230 volts through R70, R76, and isolating diode V19B. This isolating diode prevents C34 from discharging back into the power supply in case of power supply failure, thus making the fail-safe circuit independent of the power supply after the initial charging of C34. If the fail-safe cutoff pulses from the modulator drop to less than 200 pulses per second or cease entirely, capacitor C33 will begin to discharge through R78 and R79. Within a period of 2 to 7 seconds, C33 will discharge to a potential at which the thyratron will fire. This provides a discharge path for C34 through the detonator to ground and from ground through the thyratron. During this discharge, R70 divides off a negligible amount of current from the detonator. With the missile power on and no fail-safe pulses arriving from the modulator, the thyratron and capacitor C34 would act as a sawtooth generator, the pulses of which would detonate the warheads. This difficulty is overcome in the arming device by having the detonator disconnected from guidance unit circuits until after launch. Shortly after launch, an inertia-activated, 4-second timer in the arming device is set into operation. When this timer runs down, the detonator is connected to the guidance unit, arming the missile.

CHAPTER 4

CONTROL SECTION OPERATION

25. GENERAL

The control section is a principal subassembly. of the guidance section. It contains the amplifiers that provide the power to operate the missile solenoid valves in response to d-c signals from the signal data converter and the night control instruments. The night control instruments include the roll-position and roll- rate gyros, the P and Y rate gyros, P and Y accelerometers, and the stagnation pressure transmitter. Figure I-29 is a functional diagram of the missile control system.

26. TYPICAL CONTROL SEQUENCE

Refer to figure I-22 in the following discussion. Any missile maneuver may be considered to be a combination of three distinct motions. The steering fins deflect in response to an order. Air currents acting upon the deflected fins cause a second motion, rotation of the missile about its center of gravity. The third motion to be considered is the lateral acceleration of the missile as it changes course.

To satisfactorily carry out a maneuver, three circuits that produce, degenerative feedback voltages are provided in the missile. These three feedbacks correspond to the three motions involved in a maneuver.

The first of the feedbacks is a fin potentiometer feedback. Its magnitude is determined by the position of the fin. The magnitude of the fin potentiometer feedback is sufficient to cause the fins to stop at some point other than the fully deflected position if a steering order of less than 2g is sent by the MTR. For a steering order of approximately 2g or greater, the fin potentiometer feedback is not sufficient to neutralize the command; therefore, the fins will be driven to the fully detected position.

The second feedback is that of the steering rate gyros. The magnitude of the rate gyro feedback depends upon the rate at which the missile rotates about its center of gravity.

The third feedback is that provided by the action of the accelerometers. The magnitude of the accelerometer feedback is dependent upon the amount of lateral acceleration the missile is undergoing.

A steering order in excess of 2g in the P-channel will be considered. The steering order causes an unbalance in the solenoid valve, and hydraulic pressure is applied to the fin actuating cylinder. The P-fins are fully deflected. Maximum feedback is obtained from the fin potentiometer but its magnitude is not sufficient to overcome the steering order. The fins therefore remain in the fully defected position. Air currents acting upon the deflected fins cause the missile to rotate about its center of gravity with the nose moving in the direction of the intended maneuver. This rotation about the center of gravity, if continued, would eventually cause the missile to tumble end-over-end.

To prevent tumbling and to start the missile into a constant angle of attack, the P-rate gyro, sensitive to missile rotation, produces a feedback that is added to the fin potentiometer feedback. The combination of these feedback voltages is sufficient to overcome the steering order. The solenoid valve becomes unbalanced in the opposite direction. This causes the fins to move away from the fully deflected position. This movement of the fins causes a smaller feedback from the fin potentiometer. A state of balance tends to result in the solenoid valve, and the fin position become fixed. For the fins to become fixed in any position other than that of full detection, a balance must exist in the solenoid valve. The new position of the fins almost stops the rotation of the missile about its center of gravity. An angle of attack now exists between the longitudinal axis of the missile and the direction of night. Lateral acceleration results from air pressure exerted against the airframe.

The missile now picks up a lateral component of velocity as well as the longitudinal component; this results in a curved night path. Lateral acceleration is detected by the accelerometer, which provides an additional feedback voltage, the magnitude of which depends upon the degree of lateral acceleration. The accelerometer feedback is the largest controlling feedback involved in

the missile turn. The sum of these feedback voltages opposing the steering order eventually results in a condition of balance in the solenoid valve, thereby positioning the fins to maintain a slight rotation of the missile about its center gravity. The angle of attack is kept constant by this rotation of the missile.

A constant angle of attack will maintain a constant turn radius in the missile flight path. These conditions will prevail during the time the magnitude of the steering order does not change. As the missile approaches the designated course, the magnitude of the steering order decreases, permitting the feedbacks to override it. The unbalance created in the solenoid valve causes the fins to assume a lesser degree of deflection. Rotation about the center of gravity decreases and the angle of attack diminishes. With a continuing reduction in steering order, this process continues until the angle of attack reaches zero, at which time the missile no longer has a lateral component of velocity and turn has been accomplished.

27. RATE GYROS

a. **General**. Two of the rate gyros, the P- and Y-rate gyros, used in the guidance unit are identical. The third rate gyro, the roll-rate gyro, is similar to the P- and Y-rate gyros, but it has a lower sensitivity. The lower sensitivity of the roll-rate gyro is made necessary by the fact that high roll rates are encountered in the missile. Because it is desirable to have the roll-rate gyro effective at high roll rates, it is made so insensitive that it has little or no effect upon the roll servo operation after the missile has been roll-stabilized.

b. **Description and operation**. Figure I-24 illustrates a simple rate gyroscope. From the figure, the three principal axes of the rate gyro are evident. These are the spin, gimbal, and input axes. The gimbal axis might also be called the output axis because the potentiometer signal is derived from motion about this axis. In the absence of any input motion, the three gyro axes are kept perpendicular by centering springs. This is the condition for zero rate.

The gyro mounting frame or housing is rigidly attached to the missile, so that the input axis is parallel to the axis of the motion which it is desired to measure. The relationship of the missile to the axes of the three rate gyros (and also to those of the roll-position gyro) is shown in figure I-25. For the rate gyros, the direction of the input axis is the only significant direction. A simple way to remember the input axis directions for the P- and Y-rate gyros is to note that the P-rate gyro input axis must be parallel to a line joining the two P-fins on opposite sides of the missile. Similarly, the input axis of the Y-rate gyro is parallel to a line joining the Y-fins.

Any attempt to change the direction of the spin axis causes the gyro rotor to precess or to move in a direction at right angles to the applied torque. If the torque due to precession were unopposed, the gyro gimbal would tilt with the precession until the spin axis alined itself with the axis of the input torque. This condition would be unsatisfactory for the constant measurement of motions about either the P- or Y-axis. Hence, the amount of precession is limited, first by the centering springs, and secondly by stops that assure that the input axis never deviates very far from the missile axis which it monitors. When the gyro is constrained from precession, it exerts a torque against the constraint which is proportional to the speed or rate at which its spin axis is being rotated by the input force.

The displacement allowed by the constraining springs is also proportional to the rate at which the spin axis is changing direction. These relationships hold linearly for small displacements. The potentiometer wiper arm attached to the gimbal axis converts the displacement to a voltage that is also proportional to the rate of spin-axis rotation. A change in the speed of the gyro rotor will also affect the amount of precession.

To maintain a fairly constant rotor speed, a centrifugal switch is incorporated in the gyro rotor assembly. This switch inserts a resistor in series with the rotor winding if the speed becomes too great and shorts out the resistor if the speed drops below a certain value.

To prevent oscillation of the outer gimbal between its springs, an air dash pot is provided to damp the gimbal motion. The dash pot consists of a piston which is moved in a cylinder that has a small hole in the end. The air in the cylinder will resist compression or rarification when the piston is moved, thus impeding its movement. The hole will provide a constricted path for the pressure within and outside the cylinder to become equalized. Within limits, the piston, when pushed or pulled, resists movements with a force proportional to the rapidity of the movement. The degree of damping provided by the dash pot can be adjusted by a screw that varies the size of the hole in the cylinder. The optimum adjustment allows a slight overshoot of the gyro, but almost no oscillations following this.

28. ROLL-POSITION GYRO

a. **Description**. The roll-position or roll-amount gyro is an assembly consisting principally of a 2-gimbal gyroscope, a rotary solenoid that is used for caging, an uncaging relay, a motor and gear train, and a potentiometer. The gyro gimbals functionally resemble those shown in figure I-23, but they differ considerably in appearance and mechanical construction. The outer gimbal on the actual gyro is an almost complete enclosure, concealing the inner gimbal and its mechanism.

The inner gimbal, instead of completely free to turn, is limited in its travel to an angle of 170^0. This angle of travel allows a movement of $+85^0$ from the position where the spin axis is perpendicular to the plane of the outer and inner gimbal axes. Mechanical stops accomplish this limitation of inner gimbal travel, whose purpose is to provide convenience in testing. This mechanical limitation allows about 15^0 more turning movement at each side of center than should result from slant-plane turning orders, which are limited to approximately $+70^0$.

b. **Operation**. The roll-position gyro is mounted with its outer gimbal axis parallel to the missile longitudinal axis, and thus is sensitive to roll, that is, the outer gimbal remains stationary while the missile rolls around it. The purpose of the roll-position gyro is to provide a belly-down reference with respect to the slant plane. The slant plane is the plane determined by the spin axis of the rollposition gyro and the predicted point of intercept.

In other words, the gyro spin axis and the predicted point of intercept both lie within the slant plane. Without this reference, there would be no way for the ground equipment to tell which pair of fins to actuate to produce a given movement of the missile. This situation is prevented by the roll-position gyro, which, through the roll servo system, controls the ailerons at the tail of the missile to maintain a predetermined belly-down position with respect to the slant plane.

To keep the limitation of movement due to the inner gimbal stops always in the slant plane, the gyro must be preset prior to launching. If this were not done, a small turn or dive might run the inner gimbal into its stop, precess the gyro, and effectively destroy the reference axis. Before launching, therefore, the gyro inner gimbal is moved to and locked in a position in which the spin axis is at right angles to the outer gimbal axis, and the outer gimbal is connected to the preset motor gearing through a clutch. These things are done by the rotary caging solenoid, or caging relay.

When the gyro is in this condition, it is said to be caged, that is, the rotor is no longer free to maintain its axis according to the principle of gyroscopic stability. While the gyro is caged and the missile is still on the launcher, the preset motor is connected through a servo system to a synchro output of the computer, which supplies the angle to which the gyro gimbal is to be preset. This angle is such that the gyro spin axis is perpendicular to a vertical plane through the missile and the predicted point of intercept.

c. **Roll-position potentiometer**. A potentiometer is associated with the outer gimbal of the roll-position gyro. The pickoff arm is attached to the outer gimbal shaft. The roll-position potentiometer consists of 360^0, 18,600-ohm winding, having four equally spaced taps.

The taps are labeled G, H, I, and J, which correspond respectively to 1, 2, 3, and 4 on the Guidance Section Interconnecting Schematic, figure I-30. The latter notation(l, 2, 3, 4) will be used here. The positive 18-volt control signal voltage is applied to terminal 4, and the negative 18-volt control signal voltage is applied to terminal 2. Terminals 1 and 3 are grounded to the control signal ground.

The output from the potentiometer arm (at terminal 5), which is attached to the gyro outer gimbal, is applied to the input of the roll-position servoamplifier, together with inputs from the aileron potentiometer and roll-rate gyro potentiometer. From these inputs, the roll amplifier input circuits produce an error voltage, which, when amplified and applied to the hydraulic valve, actuates the ailerons to keep the missile in its belly-down position with respect to the slant plane. The roll potentiometer is in its reference position when the brush is over terminal 1, which is grounded. This terminal is the point of zero voltage, or nullpoint.

On either side of the null, the voltage from the potentiometer arm is of a polarity which will move the ailerons to produce a roll which counteracts the roll that moved the brush from the null point. As the potentiometer arm is moved farther away from the nullpoint, as by larger rolls, the voltage increases to a maximum of +18 volts at either 90^0 or 270^0. From 90^0 to 270^0, the, voltage decreases, although retaining the same polarity, to another null of 180^0 (terminal 3).

This null is an unstable null; if the wiper arm became centered over this null, it would stay there only until some slight movement displaced it to either side where it would pick off a voltage that would cause the missile to rotate so as to center the wiper arm over the correct or stable null. In normal flight, the roll-position and aileron potentiometers form most of the input to the roll amplifier, because the feedback from the roll-rate gyro is small unless the missile is rolling rapidly. The roll-position gyro potentiometer is ineffective if the roll rate is fast. The rate gyro slows the missile down to a roll rate at which the roll-position gyro potentiometer signal can position the missile in roll.

29. P- AND Y-ACCELEROMETERS

a. **General**. Two accelerometers are used in the guidance unit. One is oriented to measure lateral acceleration (centripetal acceleration) in the Y direction, the other measures lateral acceleration in the P-direction. The electrical output from each is derived by a potentiometer from the positive and negative 18-volt control signal supply. The output of each, in terms of volts per g, is supplied as a degenerative feedback signal to the corresponding control amplifier (P or Y). The input network to each amplifier algebraically adds the accelerometer signal to the fin feedback signal, rate-gyro feedback signal, and to the steering order signal, to obtain the error voltage which drives the steering servo system. Signals from the accelerometers are predominant over the other feedback signals.

b. **Description and operation**. A simplified drawing of an accelerometer is shown in figure I-26. Basically, the unit consists of a mass element in the form of a copper slug, which moves as a pendulum between springs. The displacement of the slug against the spring is a measure of force and, therefore, acceleration. The copper slug is mounted so that it can move only along one axis. By limiting the motion to one axis, only the component of acceleration along this axis will deflect the slug. That is, only the acceleration component along the sensitive axis will be measured.

Because the two accelerometers are mounted perpendicular to each other, their outputs will not interfere with each other, because an acceleration along the axis of one accelerometer will have no effect upon the other accelerometer. The output voltage is proportional to the acceleration and of opposite polarity to the steering order voltage.

A permanent magnet reduces overshoot and oscillations of the copper slug. As the copper slug moves through the magnetic field, a current is induced in the slug. This induced current produces a field that tends to oppose the magnet's field. The reaction of the two fields slows the motion of the slug, reducing overshoot and damping oscillations. The faster the slug motion, the more the induced current and the more the reacting force. As the slug changes direction, the induced field in it reverses so that the reaction works from either direction.

30. P AND Y-CONTROL AMPLIFIERS

a. **General**. Two control or steering amplifiers are utilized in the missile control section, one for the P-channel and one for the Y-channel. The circuits and operation of both amplifiers are identical. The control amplifier is a 2-stage d-c amplifier consisting of a twin-triode phase inverter and a pair of balanced-output power pentodes. The d-c gain of the control amplifier is approximately 32 decibels. The amplifier is relatively insensitive to variations in power supply voltage; a 10 percent variation in supply voltage reflects less than 0.5-db change in amplifier The various inputs to the P-control amplifier include:

1. The P-steering order voltage from the signal data converter.
2. The P-fin potentiometer feedback voltage.
3. The P-rate-gyro feedback voltage.
4. The P-accelerometer feedback voltage.
5. The buzz or dither voltage of 250 cycles per second.

The Y control amplifier has an identical set of input from the Y flight control instruments and the Y command channel in the signal data converter. The output of each control amplifier consists of two balanced 9.6-ma, d-c currents that are fed into oppositely wound solenoids that are part of the hydraulic transfer valve. An input to the control amplifier causes an unbalance in the two output currents. This current difference through the solenoids creates an unbalance that actuates the hydraulic transfer valve.

b. **Input network (fig I-31**. Each amplifier has an R-C input network that provides weighting to the input voltages so they will be summed and fed into the control amplifier in the correct proportion. The rate gyro and fin potentiometer feedback voltages are passed through R-C filtering and smoothing networks. In addition, the rate gyro input and the accelerometer input are fed through bridged-T networks that reduce the effect of the two inputs at frequencies that are close to the natural frequency of vibration of the missile.

The 250-cps buzz voltage is introduced to the pin 2 grid of V1 through a complex network consisting of resistor R39, potentiometer R38, resistor R23, capacitor C9, and resistor R22. This allows only a fraction of the available buzz voltage to be amplified by the control amplifier. This voltage is amplified by the control amplifier and applied to the solenoid valve along with the d-c output, causing a jitter in the valve plunger. The jitter overcomes static friction within the valve.

c. **Amplifier circuits**. A floating (ungrounded) 300-volt, d-c power supply voltage is brought to the amplifier across a voltage divider consisting of R15, R16, R17, R18, and R19. The junction between R17 and R18 is connected to the control signal ground to provide a positive 200 volts for the plate supply and a negative 100 volts for the cathode supply. This ground point cannot be adjusted. Potentiometer R20 equalizes the amplifier output currents during no-signal operation by varying the potential on the grid of V1A. Resistors R15, R16, and R19 are sufficiently small to provide a bleeder current heavy enough to minimize unbalance caused by circuit leakage resistances.

Twin triode V1 is a cathode coupled phase inverter. The signal across R26 is common to both triode sections so that changes in the conduction of one section are felt as grid-to-

cathode voltage changes in the other triode section. During the no-signal condition, the potential on the plate of each triode section is a positive 60 volts with respect to ground. A d-c signal applied to either grid unbalances V1, increasing conduction on one plate and decreasing conduction on the other. Resistors R24, R25, and R26 determine the operating point of the V1 phase-inverter stage and achieve optimum relationships among gain, plate current, and maximum undistorted signal output.

The plate outputs of V1 are coupled to the push-pull pentode output stage through resistors R27, R35, R28, and R29. The series combination of R37 and R30, and R37 and R36, supply negative, 2-volt bias for the pentode control grids. Capacitors C12 and C13 change the amplifier phase shift at certain frequencies to stabilize the missile feedback loops. Power pentodes V2 and V3 comprise the control amplifier output stage. Plate current now through these pentodes is balanced by cathode resistors R31 and R34, which hold the output currents equal at 9.6 milliamperes with no signal input.

When a signal is applied to the grids, the tubes unbalance, creating a differential output current in the solenoids. Resistor R33 provides coupling between the cathodes of V2 and V3 to reduce degeneration caused by cathode-follower action of the tubes when they have separate cathode resistors. The positive 200 volts is applied to the junction of two oppositely wound solenoids in the transfer valve. These solenoids are the load impedances for the output power pentodes.

31. ROLL-CONTROL AMPLIFIER

a. **General**. A roll amplifier is used in the missile control section. Circuits and operation of the roll amplifier are similar to those of the P- and Y-amplifiers. The most significant differences occur in the input network and in the cathode circuit of the output stage. The inputs to the roll amplifier include:

1. Roll-position gyro input voltage.
2. Roll-rate gyro input voltage.
3. Aileron potentiometer feedback voltage.
4. The 250-cps buzz voltage.
5. Pressure transmitter.

The R-C input network of the roll amplifier is less complex than that of the P or Y control amplifiers. There are no steering orders going into the roll amplifier. The controlling inputs are those from the night control instruments in the roll channel. These units sense the missile roll attitude and aileron position during flight. The R-C input network provides the necessary weighting to these inputs so that they will be summed and fed into the roll amplifier in the correct proportion.

b. **Circuits**. The input error voltage from the aileron potentiometer is fed into the roll amplifier through a network consisting of resistors Ri and R2, and capacitors C1 and C2. This network alters the aileron signal so it will have the correct amplitude relationship with respect to the other input signals. Capacitor C1 also couples rapid amplitude changes in the aileron signal to the grid of VIE. The roll-position gyro and roll-rate gyro inputs are fed through resistors R3 and R4 to the grid of V1A. Resistors R3 and R4 isolate these two inputs and proportion their amplitudes correctly. The buzz voltage input is applied to the amplifier in the same manner as in the P and Y control amplifiers.

All other circuit components, excluding those in the cathode circuit of V2 and V3, function exactly as in the P and Y control amplifiers. The cathodes of V2 and V3 have separate cathode resistors R21 and R23. Also, the cathodes are connected by a variable resistance located in the pressure transmitter. This resistance is variable from 0 to 3,500 ohms in response to static and dynamic pressure changes at the missile nose. When the

resistance between the two cathodes is at or near the maximum value, the cathodes are effectively isolated and cathode follower action is appreciable due to the signals being developed across R21 and R23. This cathode follower action causes degeneration and consequently loss of gain in the roll amplifier. When the resistance between the cathodes decreases toward the minimum value of zero ohms, the cathodes are, in effect, connected, and will remain at nearly a constant potential. This is caused by cancellation of the equal and opposite voltage changes developed across R21 and R23. These signals developed across R21 and R23 will always be equal and opposite because V2 and V3 are operating in push-pull. With the cathodes of V2 and V3 remaining at a constant potential, there will be no degeneration in the output stage and the gain of the roll amplifier will be increased.

When the missile is flying through rare atmosphere or at reduced speed, the roll amplifier gain increases, causing greater aileron deflection. At high speed or in dense atmosphere, the stagnation pressure is greater, so less aileron deflection is required for the same amount of roll correction. Therefore, the gain of the output stage is decreased. The over-all gain of the roll amplifier varies from 23 to 43 decibels depending upon stagnation pressure. The buzz voltage gain is nearly independent of stagnation pressure because the pressure transmitter potentiometer is shunted with a 2-ufd capacitor consisting of C8 and C9 in parallel, which has an impedance of about 318 ohms at the 250-cps buzz frequency. The load impedance for V2 and V3 is the oppositely wound solenoids in the aileron transfer valve.

With no signal input, the output of the roll amplifier consists of two balanced 9.6-ma direct current voltages that energize the solenoids in the aileron transfer valve. As in the case of the P- and Y-amplifiers, an input causes an unbalance in the amplifier output current, which in turn actuates the aileron transfer valve.

32. PRESSURE TRANSMITTER

a. **Description and operation**. The pressure transmitter is a pressure-sensing device used to vary the feedback voltages from the fin and aileron potentiometers and to vary the gain of the roll amplifier. This gain and feedback variation is a function of the sum of the static and dynamic air pressures, called stagnation pressure, acting upon the missile control surfaces. Different types of pressure sensitive elements have been used in the pressure transmitter. The sensitive element in the GA-51702 pressure transmitter is an aneroid diaphragm assembly. (In the GA-51047 pressure transmitter, a Bourdon tube is used as the sensitive element.) In the following discussion, only the aneroid diaphram type will be considered.

A schematic of such a pressure transmitter is shown in figure I-27. The active parts of the pressure transmitter consist of the two hollow metal diaphragms and two potentiometers. The interior of one of the diaphragms is evacuated and sealed off. The interior of the other diaphragm is connected through tubing to an opening at the nose of the missile where the pressure is picked up during flight. The two diaphragms are mounted on one axis (fig I-27) with the adjacent sides of the two diaphragms connected together at the center. The side of each diaphragm opposite from the other diaphragm is rigidly attached to the pressure transmitter housing. The midpoint of the connected diaphragms is thus free to move with changes in pressure. The potentiometer arms or wipers are mechanically connected to this midpoint.

Assume that the pressure at the inlet begins to drop toward zero. The pressure-sensing diaphragm begins to contract, drawing the wiper arms to the left in the figure and expanding the sealed diaphragm. With zero pressure at the pressure inlet, the wiper arms will be in their far-left position. The pressure on the outside of the diaphragm walls will not affect this setting, because the ambient pressure is equal on both diaphragms. As the pressure in the pressure-sensing diaphragm increases, this diaphragm expands, moving the point between the two diaphragms to the right in figure I-27, and compressing the

evacuated and sealed diaphragm. The potentiometer arms connected to the point between the diaphragms move respectively toward terminals 3 and 6 with the increasing pressure.

A principal advantage of using this particular arrangement of the diaphragm is that responses caused by temperature changes or pressure changes on the outside surfaces of the diaphragms are canceled at the midpoint of the diaphragms by their equal and opposite motions.

b. **Pressure potentiometers**. One of the potentiometers in the pressure transmitter is used in the roll amplifier circuit. This potentiometer varies the gain of the roll amplifier by varying the amount of cathode degeneration in the output stage in accordance with changes in stagnation pressure. The other potentiometer varies the voltage to the fin and aileron potentiometers. Figure I-28 is a simplified schematic of this circuit. The rheostat-connected potentiometer is connected in series with two 2,670-ohm resistors and a 120-ohm resistor across the plus and minus 18-volt control signal supply. At minimum pressure, the potentiometer is at minimum resistance and current flow from the -18-volt potential to the +18-volt potential is at maximum with most of the voltage being dropped across the two 2, 670-ohm resistors. The 120-ohm resistor determines the minimum voltage available for the fin and aileron potentiometers. With this minimum voltage across the fin and aileron potentiometers, the feedback voltage for a given fin position is at a minimum; consequently, the control amplifier output (with respect to this variable) is at a maximum.

As pressure increases, the pressure transmitter potentiometer resistance increases, causing a decrease in current now through the three resistors and the potentiometer itself. Voltage drop across the two 2, 670-ohm resistors decreases. The potentiometer and the 120-ohm resistor now develop a much larger proportion of the total control signal voltage, supplying an increased potential to the fin and aileron potentiometers. This increases the feedback voltage for a given fin position which, in turn, decreases the corresponding control amplifier output.

CHAPTER 5

MISSILE POWER SUPPLY AND RELAY CIRCUITS

33. GENERAL

The missile power supply is a component of the guidance section. The power supply furnishes all the voltages necessary for operation of the guidance unit circuits and the night control instruments. Included in the power supply are a transformer, a vibrator, selenium rectifier stacks, filter sections, and regulator tubes. The outputs of the power supply are as follows:

a. Positive 300-volt direct current (regulated).

b. Positive 150-volt direct current (regulated).

c. Positive 230-volt direct current (unregulated).

d. Positive 200-volt and negative 100-volt direct- current (unregulated).

e. Positive and negative 18-volt direct current (unregulated).

f. Negative 60-volt direct current (unregulated).

g. A 45-volt alternating current (for pattern modulator).

h. A 28-volt alternating current (for buzz voltage).

34. MISSILE BATTERY

The battery is a nickel-cadmium type with a potassium hydroxide electrolyte. It consists of 24 cells in series, producing a potential of 28 volts with a capacity of approximately 3 ampere hours. The battery is approximately 6-1/2 inches high, 6-1/4 inches long, and 4 inches wide. It weighs about 11-1/2 pounds. As shipped from the factory, the batteries are filled with electrolyte but completely discharged. Vent plugs must be installed in the cells before charging. When discharged through 2.8 ohms at an ambient temperature of 750 + 70 F, the battery must maintain a potential of 28 volts +10 percent for at least 15 minutes. The missile guidance unit will draw an operating current of 9 amperes from the battery during the missile's average night time of 60 seconds. Since this amounts to only one-twentieth of its total capacity, it can be seen that the battery is very conservatively rated for its intended use.

35. VIBRATOR

a. **General**. Since the only source of electrical power for the missile is a battery, some means of enabling this d-c voltage to operate a transformer must be provided. The missile vibrator serves this purpose. The vibrator utilized in the power supply is a 250-cycle type delivering 140 watts of interrupted direct current to the power transformer, where it is stepped up to provide the potentials necessary for operation of the guidance unit circuits.

b. **Operation**. Figure I-33 is a schematic diagram of the missile power supply. Negative 28-volt power is applied through surge relay K1 to the vibrating reed and the coil of the vibrator. Current flows through the vibrator coil to the lower half of the transformer primary and through the transformer to the power ground. The resistance of the vibrator coil is very large as compared to that of the lower half of the transformer primary, so that nearly all of the applied battery voltage is across the vibrator coil. The energized vibrator coil draws the reed downward against the lower contact point @in 3), which then shorts out the vibrator coil and applies the full battery voltage to the lower half of the transformer primary.

Due to spring tension and the inertia of the reed, the reed swings back past the center position and makes connection with the pin-2 contact point. This provides a path for battery current through the upper half of the transformer primary. The counter electromotive force induced in the lower half of the primary by collapse of the magnetic field is in series with the voltage being applied to the upper half. The total potential is applied across the vibrator coil, energizing it. The energized coil pulls the reed downward; the reed's inertia carries it past the center position to the lower (pin 3) contact. Again the vibrator coil is shorted and full battery voltage is applied to the lower half of the primary. Collapse of the magnetic field in the upper half of the primary induces a voltage that is in series with the battery voltage on the lower half of the primary.

At this time the reed goes back toward the upper (pin 2) contact point and the cycle is repeated. Thus, by alternate application of voltages to both halves of the primary of the transformer, followed by an induced counter electromotive force of a polarity opposite that of the applied voltage, the total voltage across the whole primary is a 45-volt, 250-cps, a-c voltage. The counter electromotive force being alternately induced in each half of the primary is always of a polarity that is series-aiding to the voltage being applied to the other half of the primary. The 45 volts developed across the primary of the transformer is utilized to power the motor in the pattern modulator.

c. **Buffer capacitor C6**. The alternate making and breaking of the vibrator contacts causes high transient voltages to be induced across the transformer primary. These transient voltages, if not suppressed, would produce excessive arcing of the vibrator contacts with resulting short vibrator life, deterioration of the output waveform, and possible transformer insulation breakdown. Capacitor C6 suppresses these transient voltages. This capacitor is connected across the primary of the power transformer to form a tuned parallel resonant circuit. Upon contact break, a shock excitation of this LC circuit occurs, resulting in the beginning of a highly damped oscillation.

The value of the capacitor is chosen so that the frequency of the shock oscillation will produce a complete flux reversal in the transformer primary during the time between reed make and break, thereby permitting the making contacts to close with nearly zero voltage between them. Additional are suppressors consisting of the resistor-capacitor combinations R2, C4, and R3, C5 are connected in parallel with the vibrator contacts to act as are suppressors. Capacitor C7 prevents "hash" from the vibrator from going back into the negative 28-volt lines where it might be coupled into other guidance unit circuits.

d. **Surge relay K1**. Surge relay K1 is a starting relay that is energized by the high transient currents which occur immediately after application of battery power and prior to the start of vibrator operation. When the surge relay energizes, current-limiting resistor R4 is inserted in series with the battery supply voltage. This current-limiting resistor drops the applied voltage to a value that will not sustain arcing of the vibrator contacts. After about 1/4 second, the surge current drops to a level at which the relay deenergizes, allowing its contacts to close and short out resistor R4. The normally-closed surge relay is designed to operate at a current level of 12 amperes and to release at 6 amperes.

36. POWER TRANSFORMER

Transformer T1 has a single centertapped primary and five separate secondaries. The transformer is electrostatically shielded to prevent r-f voltages from being present in the power supply outputs. Also, capacitors C2 and C3, and a resonant circuit consisting of C1 and inductance L1, provide additional filtering of radio-frequency. The 45-volt, 250-cps input voltage from the vibrator has an rms value of approximately 16 volts alternating current. The transformer is designed to step-up this effective 16 volts to potentials that, after rectification and filtering, are of the proper value for operation of the various guidance unit circuits.

37. RECTIFIER AND FILTER CIRCUITS

a. **Positive 300-volt supply**. Selenium rectifiers CR1 and CR2 are connected in a bridge-type circuit for rectification of the 232 volts root-mean-square from the transformer secondary. In a bridge rectifier, the peak inverse voltage across each rectifying unit is only one-half that of a conventional full-wave rectifier circuit. This permits the use of selenium dry-disk rectifiers, which have a much lower peak inverse voltage rating than vacuum tubes. Also, in a bridge rectifier, the full transformer secondary voltage contributes to the d-c output, while in a conventional full-wave rectifier circuit, only one-half of the secondary voltage is rectified. This characteristic of bridge rectifiers permits the use of smaller secondaries on the power transformer. Resistor R6 and capacitor C8 filter the fluctuating d-c output of the bridge.

A voltage regulator consisting of resistor R7 and glow-discharge tubes V1 and V2 holds the output constant at 300 volts with respect to ground. Capacitor C9 filters out the hash developed in the glowdischarge tubes. In order to regulate properly the output voltage, the available voltage supplied to the regulator section must be considerably greater than the required output. The 232-volt winding on the transformer cannot furnish sufficient voltage for this. This difficulty is overcome by connecting the negative return from the bridge rectifier to a positive potential in the positive 230-volt supply rather than connecting it to ground.

b. **Positive 230-voit supply**. Selenium rectifiers CR3 and CR4 in a bridgetype circuit rectify the 235 volts root-mean-square from the transformer secondary. Filtering of the d-c is done by a pi filter consisting of capacitor C10 and inductor L2.

c. **Positive 150-volt supply**. This regulated power supply derives its source of d-c potential through resistor R8 from the positive 230-volt supply and through resistor R9 from the positive 300-volt supply. These two resistors, together with glow-discharge regulator tube V3, regulate the output at a positive 150 volts with respect to ground. Capacitor C11 filters out the hash developed in V3 during its operation.

d. **Positive 200-volt and negative 100-volt supply**. The 328-volt rms output of the transformer secondary is rectified by selenium rectifiers CR5, CR6, CR7, and CR8. Each arm of the bridge has two rectifier units connected in series in order to withstand the higher peak inverse voltage from the 328-volt winding. The d-c output from the bridge is filtered by capacitor C12 and inductor L3. Resistor R20 and R21 form a low-drain bleeder resistance across the 300-volt potential. The junction of the two resistors is connected to control signal ground. The total resistance of R20 and R21 is 3 megohms; current flow through this voltage divider is not heavy enough to establish the ground point of the power supply. The ground point for this power supply is actually established in the P and Y control amplifiers and the roll-control amplifier. Each of these amplifiers has a voltage divider incorporated in it that establishes the ground point as well as other circuit potentials necessary for amplifier operation. Capacitors C13 and C14 in the power supply lower its impedance as a voltage source for the control amplifiers.

e. **Positive and negative 18-volt supply**. A bridge rectifier circuit consisting of selenium rectifiers CR9 and CR10 provides full-wave rectification of the 55-volt rms source from the transformer secondary. Capacitor C15 and inductor L4 comprise the filter section. Variable resistor R11 adjusts the total output of the power supply about the optimum value of 36 volts. Resistors R12 and R13 establish the ground point for the supply. The junction of the two resistors is connected to the control signal ground. Because R12 and R13 are of equal resistance, the output of the power supply is a balanced positive and negative 18 volts.

f. **Negative 60-volt supply**. Selenium rectifiers CR11 and CR12 rectify the 104-volt rms power source from one of the transformer secondaries. Capacitor C16 and resistor R14 filter the fluctuating direct current from the rectifier. Resistor R15 is a bleeder resistance.

38. RELAY AND SWITCHING CIRCUITS (fig I-30)

a. **Cage relay**. In physical construction, the cage relay is actually a rotary solenoid. The cage relay coil receives its power from the ground equipment and is actuated while the missile is on the launcher. When this relay is energized, it performs three functions: First, it cages the roll-position gyro, forcing the inner and outer gimbals into the proper perpendicular alinement by means of a cam and plunger mechanism. Second, it closes contacts that enable operation of the gyro preset motor. Third, it opens the caging-indicator contacts. The cage relay and uncage relay both control the same set of contacts.

b. **Uncage relay**. When the uncage relay is- energized at the launch order, its armature, which is the latch holding the caging cam in place, pulls out of the caging cam and uncages the roll-position gyro; The uncage relay also restores the ground reference to the caging indicator lead and opens the preset motor circuit.

c. **Transfer relay**. In its normal or deenergized position, before the missile is launched, the transfer relay provides for application of power to the circuits of the guidance section from an external source in the ground equipment. Vibrator power and heater-and-gyro power are supplied to the contacts of the relay on two busses that enter the guidance unit at terminals P and S of receptacle J1 on the autopilot control servo chassis. The vibrator power is routed from transfer relay contacts 5 and 6 to the vibrator via the coil of the vibrator starting relay in the power supply. The heater-and-gyro power goes directly from transfer relay contacts 8 and 9, and from 2 and 3, to the tube heaters, gyro motors, and the coil of the preset relay. The preset relay does not energize, because its ground circuit is held open by the booster separation switch.

At the fire command, the transfer relay is energized and connections from the external 28-volt source are broken at relay contacts 3, 6, and 9. Simultaneously, the 28-volt power from the internal battery is supplied to the vibrator, heaters, and gyros through three other contacts (4, 7, 1) on the transfer relay. In addition, a holding circuit is set up with contacts

10 and 11 that routes the internal battery voltage to the coil of the transfer relay, keeping it energized.

d. **Inertia switch**. The inertia switch is operated physically by acceleration of the missile at the start of boost. Prior to launch, the roll-position gyro is uncaged and the transfer relay is energized; if this were not done, the inertia switch would energize the uncage relay and energize the transfer relay, uncaging the roll-position gyro and placing the missile on internal battery power.

e. **Separation switch**. The separation switch is not a part of the missile guidance section, but is located on the boattail of the missile. This switch is held open by the booster and closes at booster separation. When the switch closes, ground is applied by means of a wire running through tunnel 3 to terminal Y on receptacle J1 of the autopilot central servo chassis.

f. **Preset relay**. In its normal or deenergized condition, the preset relay contacts connect the roll-position potentiometer to the gyro preset servo system in the ground equipment. The connection is made from terminals f, h, k, and j on receptacle J1 of the autopilot control servo chassis by means of wires running through tunnel 3 to the ground power receptacle which, in turn, connects to the ground power plug on the launching rail. These connections are broken when the missile is launched, as are the preset motor connections. However, the preset relay remains deenergized at launch, and the roll-position potentiometer supplies no signal to the roll amplifier (which does receive an input from the roll-rate gyro).

Approximately 2.5 seconds after launch, the booster burns out and is separated from the missile by air drag. When this occurs, the booster separation switch closes. It applies ground to the preset relay coil·circuit, energizing the relay. When the relay energizes, +18 volts, -18 volts, and control signal ground are applied to terminals 4, 2, 1, and 3, respectively, of the roll-position potentiometer. The roll-position potentiometer then supplies the roll-stabilizing signal to the roll amplifier for correction of roll attitude. The operation of the preset relay completes the switching sequence in the guidance section assembly.

CHAPTER 6

GUIDANCE UNIT REMOVAL

39. REMOVAL OF THE GS-16725 GUIDANCE UNIT

a. The following procedure may be used for the removal of the GS-16725 guidance unit from an assembled Nike I missile:

1. Place the missile on the missile dolly so that tunnel 1 is on top.

2. Remove the screws attaching the forward section of tunnel 1 to the missile body. Remove the forward section of tunnel 1 and place the screws back in the tunnel mounting studs.

3. Revolve the missile within the handling rings and remove tunnels 2, 3, and 4 in the same manner. Revolve the missile on the missile dolly so that tunnel 1 is on top after completion of the operation.

4. Disconnect the two cable receptacles from their plugs under tunnel 3 of the guidance section.

5. Disconnect the hydraulic-system fluid-return line at the steering fin section under tunnel 2. Cap both the line and the fitting to prevent entry of foreign matter.

6. Disconnect the hydraulic-system air-pressure line at the steering fin section under tunnel 2. Cap both the line and the fitting.

7. Disconnect the hydraulic-system fluid-pressure line at the steering fin section under tunnel 4. Cap both the line and the fitting.

8. Place a guidance section dolly under the guidance section, and secure the two sector rings around the guidance section. Take care to avoid crushing the hydraulic system lines under the sector rings.

9. Remove the eight bolts at the aft end of the guidance section that attach it to the forward ring of the central body section. With the guidance section resting on the dolly, move the dolly forward, being careful not to damage the hydraulic-system lines that protrude from the central body section.

10. Remove the battery box with the guidance section rotated so that the battery box is facing upward.

11. Remove the battery stud.

12. Remove plugs JE-l and JE-2 by extracting their six mounting screws.

13. Disconnect the two coaxial cables from the delay line and remove the delay line.

14. Disconnect the stagnation pressure line at the fitting leading to the outside of the guidance section housing.

15. Detach the dome ring from the ah end of the guidance section housing by removing five screws.

16. Remove the dome.

17. From the aft end of the guidance section, turn each Of the four hexagonal nuts located on the receiver-transmitter-signal data converter base plate one-half turn counterclockwise.

18. Slide the rear section of the guidance unit out the aft end of the guidance section housing.

19. Turn each of the five hexagonal nuts located on the autopilot control servo base plate one-half turn counterclockwise.

20. Grasp the forward section of the guidance unit by the handle provided and slide it out of the aft end of the guidance section housing. Exercise care not to catch any of the guidance unit's cables on the openings in the guidance section housing. If it is desired to remove only the rear section of the guidance unit, steps 10 through 14 may be omitted. The rear section of the guidance unit contains r-f detectors, amplifier-decoder, modulator, waveguide assembly, and signal data converter.

b. The GS-16725 guidance unit may be installed in the missile by reversing the above procedure.